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CANOLA MEAL AS A PROTEIN SUPPLEMENT FOR SWINE

by

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ABSTRACT

Six experiments were conducted at The University of Alberta Swine Unit utilizing 454 pigs to determine the replacement value of canola meal (CM) (rapeseed meal containing less than 3 mg/g glucosinolates) for soybean meal (SBM) in the diets of starter pigs (7-27 kg liveweight). In the first two experiments, CM replaced either 0, 25, 50, 75 or 100% of the protein supplied by the SBM supplement in isonitrogenous and isoenergetic diets based on barley, wheat and oat groats. In both studies, CM replaced up to 50% of the protein supplement (17% in the diet) without reducing the average daily gain (ADG) of the pigs, although average daily feed (ADF) was lower ($P<0.05$). When CM comprised 75% or more of the SBM supplement (27% or more in the diet) the ADG and ADF were significantly reduced. The efficiency of feed conversion to body weight gain (FCE) was similar for all dietary levels of CM. Lysine supplementation did not significantly improve starter pig performance. Each one percent addition of CM to the diet resulted in a linear ($P<0.01$) reduction in ADF and ADG by 4 and 2 g, respectively.

In a third experiment the utilization of nitrogen (N) and amino acids (AA) when CM was fed at graded levels of protein to starter pigs was examined. The apparent dry matter and energy digestibility decreased linearly ($P<0.05$) as the level of protein in the diet increased. The apparent N digestibility and the apparent net protein utilization

(NPU) increased linearly ($P<0.05$) as the level of dietary protein increased. The apparent and true N balance significantly increased with increasing protein levels. The apparent fecal availabilities of most of the indispensable and dispensable amino acids (AA) increased linearly ($P<0.05$) and/or quadratically ($P<0.05$) as the level of protein in the diet increased. The true biological value and NPU of CM for starter pigs was 70.1 and 57.3, respectively.

The last three experiments were designed to examine the palatability of CM when included in starter pig rations at various levels. In the fourth experiment, pigs were given a choice between a SBM control ration and one of four isonitrogenous, isoenergetic rations containing either 5,10,15 or 20% CM. Pigs fed from five to nine weeks of age consumed two and one-half times to seven times more of the SBM control diet than diets containing 5 to 20% CM, respectively. When given a choice, pigs consumed significantly less of the diet containing 5% CM than the SBM control diet and significantly reduced their consumption of the CM supplemented diets as the level of CM in the diet increased to 20%. In the fifth experiment, pigs were given prior adaptation to a 10% CM for varying lengths of time and then given a choice between the 10% CM diet and a SBM control diet. No significant differences were observed due to length of adaptation to a 10% CM diet and pigs' subsequent selection preferences when given a choice between the 10% CM diet and the SBM control diet.

In the last palatability study an attempt was made to influence the consumption of diets containing CM by the addition of flavour additives. Monosodium glutamate (0.15%), dextrose (10%) and corn oil (4-5%) were included in diets of starter pigs in which CM replaced 50 or 100% of the protein supplied by the SBM supplement. No significant differences in performance were attributed to the inclusion of these flavour additives. Pigs fed a SBM control diet and a 50/50 SBM/CM mixture with dextrose grew faster ($P<0.05$) than pigs fed the 100% CM supplemented diet with or without the three flavour additives. Pigs fed the 50/50 SBM/CM mixture with dextrose consumed more ($P<0.05$) feed than pigs fed the 100% CM supplemented diet with or without the flavour additives. The FCE's were similar ($P>0.05$) for all diets. No significant changes were found in consumption patterns of any of the diets fed between week one and week four of the experiment.

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I. INTRODUCTION

Botanically, the word rape means turnip and is derived from the Latin word rapum. Production of rapeseed (RS), an oil bearing seed from plants of the *Brassica* genus, is of ancient origin and recorded usage is known from early Sanskrit writings of 2000-1500 B.C. (Appelqvist and Ohlson 1972). The cultivation of RS and its usage as a lubricant, luminant and a soap are reported to have occurred in Europe as early as the thirteenth century (Appelqvist and Ohlson 1972). Peak European RS production occurred during the mid-1800's and shortly thereafter rapidly declined due to stiff competition with imported mineral oil for illumination and vegetable oil for margarine and soap production. Presently, RS ranks fifth worldwide in oilseed production, with China and India as the main RS producers (ANON 1982).

There are two main species of rape grown for seed in Canada. These are *Brassica campestris* (summer turnip rape) which makes up about 40% of the total acreage grown, and *Brassica napus* (summer rape) which makes up the remaining 60% of the acreage grown for seed in the Praire provinces (ANON 1982).

The *B. campestris* or Polish rape is early maturing (86 days) and thus suited to northern areas for production. The shorter growing period, and the greater drought and shattering resistance of the pods during harvesting are the main reasons why this species is grown in Canada (Downey and Klassen 1977).

The *B. napus* or Argentine rape is later maturing (104 days) making these varieties more suited to the southern areas of production. *B. napus* produces a greater yield of seed and is resistant to staghead, a white rust which is a major disease problem in areas of *B. campestris* production (ANON 1980).

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II. CANADIAN RAPESEED PRODUCTION

Rapeseed (RS) grown and processed is important to Canada as an export crop (75-80% of the crop has been exported in the recent past) and as a domestic food supply (ANON 1978). Approximately 52% of the vegetable oils such as margarines, shortenings, salad and cooking oils consumed in Canada are of RS origin (ANON 1983). Because of its economic and nutritional importance to Canada, plant breeders have been working to improve the agronomic performance of the crop as well as the quality of the oil and the high-protein residual meal (rapeseed meal) that remains after oil extraction.

Early plant breeding resulted in better adapted varieties with increased seed and oil yields. In the late 1960's, cultivars producing a new kind of oil were developed. These cultivars were essentially free of erucic acid, a long-chain fatty acid component that was characteristic of oil from most *Brassica* seeds. Thirty-three to 50% of the original RS oil triglycerides were from this monenoic fatty acid (C22:1)(ANON 1978). Various studies reported that diets containing more than 10% RS oil of the high erucic acid cultivars caused fat accumulation in heart muscle, some necrotic cardiac lesions and in some cases, an overall reduction in animal performance (ANON 1978). Although the agronomic performance of these new cultivars - Oro, Zephyr and Span - was not equal to the agronomic performance of the existing high erucic cultivars, producers

and processors realized the importance of their oil quality. Downey and Klassen (1977) claim that by 1973 more than 85% of the Canadian rapeseed acreage was seeded with low-erucic acid cultivars. Combining the low erucic acid characteristic with high seed yield in the Midas variety of *B. napus* and the Torch variety of *B. campestris*, both released in 1973, brought about a complete changeover to the new oil type (ANON 1978).

Rapeseed meal (RSM) derived from these new cultivars is considered to be a valuable livestock feed supplement. Feeding high levels of RSM, however, may result in metabolic disorders, reduced weight gains and feed intake, especially when fed to swine and poultry (Aherne and Kennelly 1982). This problem was shown to be largely due to the presence in RSM of certain sulfur compounds known as glucosinolates (Bell 1955). In 1967 an unadapted European *B. napus* cultivar, Bronowski, was discovered that contained a much lower level of glucosinolates and was subsequently introduced into Canadian breeding programs (Downey and Klassen 1977). Bronowski, however, contained relatively high levels of erucic acid and was not well adapted to our climate, producing seed of substandard quality (Bell 1975).

The licensing of Tower in 1974 marked the beginning of a change in rapeseed production in Canada to varieties which produced both low erucic acid oil and low glucosinolate meal (Castell 1977). RS with a low glucosinolate (LG) content produced an improved quality protein meal which can be

included at higher levels in feeds formulated for livestock and poultry (Bowland 1974; Bell 1975; Clandinin and Robblee 1981). Consequently, LG-type RSM is a more readily marketable product than meal from varieties such as Midas and Torch. Canada leads the world in the production of LG-type RS. About 91% of Canada's 1982 RS crop of 4.098 million acres was of the LG-type (ANON 1982). The most widely planted variety in Western Canada on an acreage basis is the Polish type (*B. Campestris*), Candle, followed in order by the *B. napus* varieties, Regent, Altex and Tower (ANON 1982).

Altex, licensed in 1978, is particularly well adapted to central Alberta and the parkland area of Saskatchewan because it matures several days earlier than Tower or Regent. It is equal to Regent in seed yield. Altex is one or two inches shorter than Tower and Regent, however, it is somewhat more susceptible to lodging (ANON 1980).

Candle, which is the only licensed low erucic, LG-type *B. campestris* variety, was grown on about 1.3 million acres in 1982, comprising 52% of the total Alberta RS crop (ANON 1982). This variety was developed by interspecific hybridizations involving the species *B. napus*, *B. campestris*, and the mustard species *B. juncea*, producing *B. campestris* with an even lower glucosinolate level than Tower, and with a yellow seed color (Downey and Klassen 1977).

The development of yellow seed color had been a breeding objective for a number of years because yellow seeds have a thinner seed coat than brown seeds, and consequently a lower crude fiber content (Bell and Shires 1982). In addition, yellow seeds contain 2 to 3% more oil than brown seeds, and frequently a higher protein content.

To differentiate this new LG-type of RS and its products from those derived from high glucosinolate RS, the name "Canola" was contrieved. This new name refers to oil, meal, protein extracts, seed and seed hulls from or of varieties with 5% or less erucic acid and 0.3% or less of the normally measured glucosinolates (3-butenyl-, 4-pentenyl-, and 2-hydroxy-3-butenyl- (McGregor 1980).

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III. COMPOSITION OF RAPESEED MEAL

A. Protein and amino acids

The protein content of RSM varies with the climate and soils conditions underwhich the plant was grown, type of cultivar from which the meal was produced and the processing methods used in its preparation. The crude protein content of RSM from Candle is approximately 35% while that from Tower, Regent or Altex is 38-39% (Clandinin and Robblee 1981). On an equivalent protein basis, the amino acid content of RSM compares favourably with soybean meal (SBM) (Bowland 1976). Bell (1975) indicated that RSM has a higher methionine-cystine content than SBM while SBM contains more lysine. From this standpoint these two protein supplements complement each other in terms of their combined amino acid balance.

Of primary concern is the level and availability of lysine in RSM since the level of lysine is comparatively low and availability may be lower than in SBM (Sauer *et al.*1982). Bowland (1976) reported that autoclaving RSM at 121°C for 2 and 4 hours reduced the lysine content of the RSM by 20 and 38%, respectively. The available lysine level in RSM may also be influenced by processing technique and the degree of heat treatment (Josefsson 1975).

B. Energy

Full-fat rapeseed has a high gross energy content of about 6.6 kcal/g due to its high oil content (Ochetim 1977). The energy content of the meal, however, is variable depending on the oil remaining in the meal following extraction and the amount of gums which are added back to the meal. This may be as high as 6-7% using the expeller process or as low as 2% using solvent extraction methods (Youngs *et al.*1981).

The actual metabolizable energy (ME) and digestible energy (DE) values for RSM are relatively low compared to SBM, particularly for chickens. Recent data reported by Clandinin and Robblee (1981), indicated that Tower RSM contains 1900 kcal/kg and 2000 kcal/kg of ME for growing and adult poultry, respectively.

Bowland (1976) and Clandinin and Robblee (1981) both reported a ME value for RSM of 2700 kcal/kg for swine. Bowland (1976) claims that the low ME of RSM is due primarily to the high fiber content of the meal (approximately 13%). Ochetim (1977) states present methods of processing rapeseed have little or no effect on the crude fiber content of the meal.

Clandinin and Robblee (1981) suggested that the Canadian method of removal of the hulls, by regrinding and air-classification, has resulted in a RSM protein content similar to SBM. The meal, however, may be so finely ground that it causes feeding problems (Bayley and Hill 1975).

Aherne and Kennelly (1982) reported that French and Swedish workers have removed the hull from the seed before oil extraction, resulting in a protein meal that is more acceptable as a feed supplement than the hull-free meal produced by the Canadian method. In a study involving rats, Clandinin and Robblee (1981) reported that by reducing the fiber content of RSM by 60% using the French process of dehulling, the digestibility of RSM protein and the ME content of the meal were increased to those of SBM. They note, however, that one disadvantage of the European approach is that a small amount of oil is lost in the hull fraction. Sarwar *et al.* (1981) reported that the removal of RS hulls increased DE and ME and the digestible crude protein content, but that the inclusion of hulls in high energy, non-rapeseed meal diets had no adverse effects on growth rate or feed efficiency when fed to mice.

Clandinin and Robblee (1981) point out that hull removal would result in a meal essentially free of condensed tannins since they are for the most part located in the hulls of RS. This process could improve the protein quality of RSM since tannins have been shown to have a negative effect on nitrogen digestibility (Mitura 1982).

C. Minerals

The mineral content of RSM varies due to growing and processing conditions but generally it is rich in calcium (0.61%) and phosphorus (1.9%) (Bragg 1974). Both calcium and

phosphorus occur at approximately two-times the levels found in SBM and should provide a reasonably good source of these relatively expensive components. Clandinin *et al.* (1972), however, reported that from 34 to 71% of the phosphorus may be present as phytin phosphorus and therefore the availability of phosphorus in RSM may be only slightly greater than that found in SBM.

RSM is also a good source of iron and magnesium (Clandinin *et al.* 1978) and selenium, manganese and zinc (Ochetim 1977). Ochetim (1977) also indicates that RSM is rich in choline, niacin, folic acid and riboflavin, but the content of pantothenic acid and thiamin is low.

D. Ether extract

The ether extract of Canadian RSM tends to be higher than that of SBM (Clandinin and Robblee 1981). This is because in Canada RS gums are added back to RSM at about the 1.5% level. The gums are obtained during the refining of RS oil and consist of glycolipids and phospholipids and variable amounts of triglycerides, sterols and fatty acids. The addition of gums to RSM increases the energy value of RSM. Clandinin and Robblee (1981) found that the addition of up to 6% of RS gums to RSM had no detrimental effects on the feeding value of RSM for broilers or layers. McCuaig and Bell (1981) reported that neither source (high or low glucosinolate oils) nor level of additional gums (1-4%) had any effect on the rate of growth or feed consumption when

fed to growing-finishing pigs.

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IV. ANTI-NUTRITIVE FACTORS AFFECTING THE FEEDING VALUE OF RAPESEED MEAL

A. Glucosinolates

The nutritional value of RSM has been of concern due to the presence of glucosinolates in the meal, agents considered responsible for the goitrogenic properties of RSM. Although biologically innocuous themselves, conditions leading to the hydrolysis of glucosinolates yields a variety of goitrogenic and toxic compounds (Josefsson 1975). These compounds are also responsible for the pungent flavours of RS (Chubb 1982) and they have been shown to cause growth depression and thyroid abnormalities in swine (McKinnon and Bowland 1977; McKinnon and Bowland 1979; Ochetim *et al.*1980a, 1980b).

The level of glucosinolates in CM is about one-eighth that of the older Canadian high glucosinolate RSM and less than one-tenth that of European high-glucosinolate RSM (Aherne and Kennely 1982). Clandinin and Robblee (1981) reported glucosinolate values for Tower and Candle CM of 1.04 and 0.62 mg/g of the meal, respectively, whereas Bell and Jeffers (1976) reported values of 8.5 and 6.3 mg/g of glucosinolates for Canadian high glucosinolate *B. napus* and *B. campestris* RSM, respectively.

Glucosinolates are not considered to be toxic themselves. Goitrogens derived from the enzymatic hydrolysis of glucosinolates, however, can cause thyroid hypertrophy by

diminishing the supply of thyroid hormone available to the body. This is accomplished by either reducing the supply of iodine available to the thyroid or by interfering with organic binding of the iodide ion which reaches the thyroid (Paik 1980).

Myrosinase

Hydrolysis of the glucosinolates occurs by the activity of an enzyme with the trivial name myrosinase (systematic name: thioglucoside glucohydrolase (E.C. 3.2.3.1))(Fig.IV.1). When the plant or seed is crushed in the presence of sufficient amounts of water (approximately 13% moisture in the seed), the glucosinolates are autolyzed by the liberation of myrosinase (Youngs *et al.*1981). The major toxic compounds formed from this breakdown are isothiocyanates, thiocyanates, nitriles and goitrin (Ochetim 1977; Sarwar *et al.*1981). The pattern and amount of breakdown products from glucosinolates varies with the nature of the glucosinolates and myrosinases and with different hydrolytic conditions (Paik 1980). Thus great care must be taken in processing of the seed to prevent formation of these compounds.

Greer and Deeney (1959) have demonstrated the existence of myrosinase in certain bacteria. An organism with the capacity of producing this enzyme is *Escherichia coli*. Therefore, although proper procedures of processing which destroy rapeseed myrosinase exist, a portion of the glucosinolates in the meal will still be degraded by the gut

microorganisms via an enzyme comparable to RS myrosinase (Chubb 1982). There is, however, little indication in the literature of the extent of activity of this enzyme in the gut, although it does not seem to significantly influence the feeding quality of properly prepared RSM.

Goitrin

Goitrin (5-vinyl-2-oxazolidinethione), the most active breakdown product, is produced from the hydrolysis of 2-hydroxy-3-butenylglucosinolate (Chubb 1982). The goitrogenic mode of action of goitrin appears to either prevent organic binding of iodine or to prevent binding of mono-iodotyrosine or di-iodotyrosine to form either tri-iodothyronine (T_3) or thryoxine (T_4) (Ochetim *et al.*1980a). The net reduction in circulating T_3 and T_4 results in a stimulation of the hypophysis to produce thyroid stimulating hormone (TSH) with the end result being enlargement of the thyroid gland.

Thiocyanate

The compound thiocyanate has been shown to prevent active uptake of iodine (Ochetim *et al.*1980a). The goitrogenic effect of thiocyanate ions can be prevented or inhibited by increasing the iodine content of the diet (Van Etten *et al.*1969; Ochetim *et al.*1980b). The isothiocyanate ion is relatively unstable, undergoing further hydrolysis to form a free thiocyanate ion (Van Etten *et al.* 1969).

Nitriles

The final group of endogenous breakdown compounds are nitriles. Paik (1980) from a review of the literature suggested that since nitriles are much more toxic than goitrin, which in turn is more toxic than either isothiocyanate or thiocyanate, nitriles and goitrin tend to be of greater importance in the utilization of RSM's by livestock. Van Etten *et al.* (1969) demonstrated that nitriles are toxic to rats, causing death through lesions in the liver and kidneys. Srivastava *et al.* (1975) reported similar results for both rats and chicks.

B. Tannins

Another group of compounds which may influence the feeding value of RSM are the tannins (polyflavoid compounds which tend to accumulate in the seeds of the rape plant)(Leung *et al.*1979). Both hydrolyzable and condensed tannins have been shown to have adverse effects on the performance of mice (Glick and Joslyn 1970), poultry (Clandinin 1961; Vohra *et al.*1966) and swine (Almond *et al.*1979). Mitaru (1982) concludes, however, that the majority of RSM and CM tannins are unreactive and unextractable and thus do not show adverse effects on animal growth, and digestibility of energy and nitrogen by non-ruminants. Yapar and Clandinin (1972) demonstrated that condensed tannins extracted from RSM and added to SBM significantly reduced the ME value of SBM. Fenwick and

Hoggan (1976) discussed the difficulty in measuring the tannin content of RSM, but indicate that no tannin-induced metabolic disorders should occur in chicks provided RSM is kept below 10% of the diet.

C. Sinapine

Sinapine is a choline ester of 4-hydroxy-3,5-dimethoxycinnamic acid occuring in both *B. napus* (1.9%) and *B. campestris* (1.4%) (Mueller *et al.*1978). Sinapine may be responsible for some of the unpalatability of RSM due to its bitter taste (Schwarze 1949). Clandinin (1961) and Josefsson and Uppstrom (1976) found that sinapine produced no growth depressing effects when fed to chicks and mice, respectively. Sinapine is the causative agent via trimethylamine in "fishy" eggs produced by brown shelled egg layers (Hobson-Frohock *et al.*1978; Goh *et al.*1982a, 1982b). It is of interest to note that some animals may be classified as "tasters" and "non-tasters" according to their reactions to the bitter phenylthiourea compounds (PTC) (Goatcher and Church 1970). These groups can be further broken down into sensitive and insensitive groups according to their reactions to quinine. Sensitive "tasters" of the bitter PTC and quinine, differentiate foods more than do "non-tasters" of the same two bitter compounds (Fischer *et al.*1961). Thus ruminants, poultry and mice may not respond to the sinapine of CM in the same manner as swine (Kare *et al.*1965).

D. Fiber

The fiber content of RSM varies from about 12 to 16%, depending on the cultivar and the processing methods employed during oil extraction (Aherne and Kennelly 1982). RS contains 16.5-18.7% hull on a dry matter basis (Appelqvist and Ohlson 1972). After oil extraction the resulting meal contains about 30% hulls. Rapeseed hulls contain about 20% cellulose, 23% lignin, 9% pectin, 20% protein and 5% ash, but little free carbohydrate or lipid (Bell and Shires 1982). Bell and Shires (1982) reported that hull from the brown seed of *B. napus* contained more fibre and lignin than of hulls from the yellow seed of *B. campestris*.

As mentioned, removal of the hulls of RSM may improve its feeding value by lowering the fiber content of the meal. Results from experiments involving hull removal have been promising, although in practical application, due to the small grain size of RS, this practice has yet to prove economical. Kennelly *et al.* (1978), however, found that a 2% reduction in the fiber level of RSM when fed to rats did not improve their performance. Bayley and Hill (1975) reported that reducing the fiber level of RSM to 8% had no significant influence on its DE or ME values for 25 kg pigs. Increasing the dietary level of CM hulls from 0 to 30% in the diets of growing pigs depressed the digestibility of dry matter, energy, crude fibre and ether extract (Bell and Shires 1982). Bell and Shires (1982) indicated that the

protein of hulls of *B. napus* (cv Tower) was indigestible, whereas that from hulls of *B. campestris* (cv R-500) was 20% digestible.

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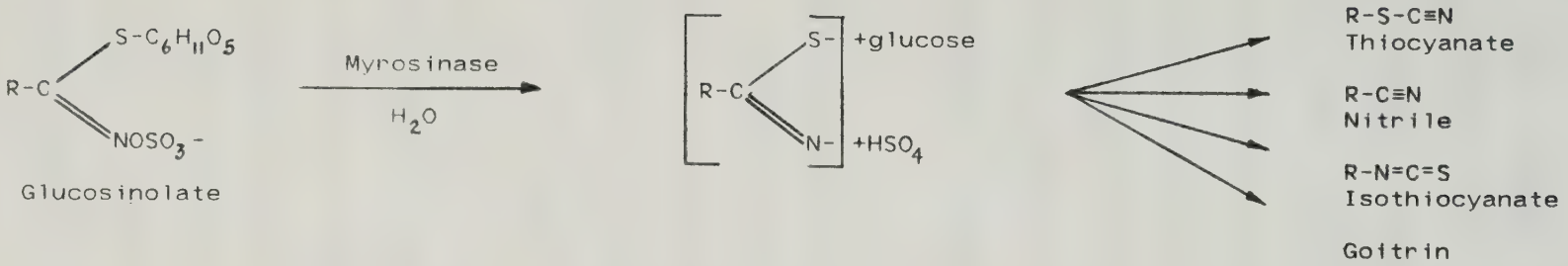
Figure IX.1. Hydrolysis of glucosinolates and their respective breakdown products common to Brassica plants.[3]



TYPE	R-GROUP	COMMON NAME	AMOUNT[1] (mg/g)
Brassica campestris (Polish rape)	3-Butenyl	Gluconapin	18-44
	2-hydroxy-3-butenyl	Progoitrin	2-20
	4-pentenyl	Glucobrassica-napin	
Brassica napus (Argentine rape)		Gluconapin	10-22
		Progoitrin	18-50
		Glucobrassica-napin	0.5-10
Brassica napus (cv Bronowski)		Gluconapin	1-4
		Progoitrin	0.1-23
		Glucobrassica-napin	

[1]Content in the meal on an aid-dried basis.
[2]Adapted from Chubb 1982, pp. 30.
[3]Anywhere from 1-7 glucosinolates may be present in the RS plant, occurring either in the root, stem, leaf or seed.

V. INFLUENCE OF NEW PROCESSING METHODS OF RAPESEED ON THE FEEDING VALUE OF RAPESEED MEAL

The present improved value of RSM as a livestock feed, aside from the progress that has been made in the breeding of the new LG-type varieties, can be attributed to the development of processing methods which have been directed towards destruction of the myrosinase enzyme of RS while still maintaining a good quality of protein. Processing is accomplished in three stages: (1) crushing of the seed to provide access to the oil; (2) cooking to destroy the myrosinase enzyme and (3) extraction of the oil (ANON 1978).

A. Heating and Crushing

Youngs *et al.* (1981) indicate the necessity in maintaining a moisture level of between 6 and 10% to prevent hydrolysis of glucosinolates by myrosinase (as hydrolysis will occur quickly at moisture levels at or above 13%). Following the crushing of the seed, again to minimize hydrolysis of the glucosinolates, the crushed seed is heated as rapidly as possible to 80 to 90°C. This process serves to inactivate the myrosinase enzyme.

The crushing and heating processes are perhaps the most crucial in determining the quality of the final product. For example, with insufficient heat or heat for an inadequate period of time, hydrolysis of the glucosinolates will result thus lowering the feeding value of the meal. On the other hand, too much heat or for too long a period of time will

jeopardize the protein quality, again lowering its feeding value (Josefsson 1975). Considerable depression of lysine availability may occur from improper processing techniques (Ochetim *et al.*1980).

Youngs *et al.* (1981) reported that excessive heat will also affect the oil quality. Temperatures of 110°C and above, particularly in the presence of water, reduces the ability to hydrogenate the extracted oils. This reaction is due primarily to the presence of the hydrolysis products of the glucosinolates. Therefore, the final product's quality is greatly influenced by processing procedures.

B. Commercial methods

The final processing steps of RS are extraction and purification of the oil. Three methods of extraction are presently utilized in Canada and all result in a good quality product if properly employed (ANON 1978).

1. The first of these is the expeller-pressing-extraction method. The method is purely a mechanical means of simply pressing oil from the crushed cooked seeds. The method is reasonably effective, however, the resulting meal usually still contains 6-7% oil.
2. The second method is prepress-solvent-extraction. Ground cooked rapeseed is subjected initially to the expeller process which lowers the oil content of the seed to 15 to 20%. The meal is then subjected to extraction using hexane by one of several means. The resulting meal

contains only about 2% oil.

3. The final method employs only solvent extraction of the full-fat-ground-cooked rapeseed. Again the result is a product containing about 2% oil.

The temperature employed during the extraction process will directly affect the quality of the resulting meal. Youngs *et al.* (1981) claim temperatures of less than 105°C must be employed when extracting oil from the RS, otherwise the quality of the protein in the meal will be lowered.

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VI. RAPESEED AND CANOLA MEAL FOR SWINE

When rapeseed meal (RSM) from the main two species of RS in Canada became available to swine producers back in the early 1950's, disturbing results began to emerge. Reductions in growth rate, feed consumption and digestibility coefficients for energy and nitrogen along with functional abnormalities of the liver and kidneys were associated with the feeding of RSM to swine (Bell 1955; Hussar and Bowland 1959; Bayley *et al.*1969;Cho and Bayley 1970). The observed adverse effects related to RSM when fed at high levels were partially attributed to the hydrolysis products of the glucosinolates found in the meal (Bowland 1971; McKinnon and Bowland 1979). When the new "OO" (low erucic acid, low glucosinolate) cultivars of RS such as Tower emerged in 1974, hope was again restored for the use of RSM as a protein supplement in swine rations (Castell 1977a). Comparative studies between the high and low glucosinolate varieties indicated an improvement in pig performance, although some reductions in performance were still found at high supplementation levels (Bowland 1974; Bell 1975; McKinnon and Bowland 1977). Current recommended levels of inclusion of canola meal (CM) (low erucic acid RSM containing less than 3 mg/glucosinolates) in swine rations may vary according to the age of the animal or stage of production, cultivar used, basal ingredients and their relative nutritional values, the processing methods employed during oil extraction and the experimental methods and

procedures followed.

A. Starter pigs

Bowland (1974) observed that from 6 to 17 kg liveweight, pigs fed a barley-wheat-based diet containing 11.5% LG-type RSM (cv Bronowski) gained weight significantly more slowly than pigs fed a SBM control diet. In another study, Bowland (1975) indicated that CM (cv Tower) could completely replace (20% CM in the diet) soybean meal (SBM) in the diets of young pigs from 7 to 14 kg liveweight without adversely affecting performance. No significant differences in the utilization of dietary nitrogen or energy were observed between diets supplemented with SBM, CM or a 50/50 mixture of SBM/CM. Bowland *et al.* (1975) reported that RSM (*B. Napus* 1788) could safely replace approximately 56% of the SBM (on a nitrogenous basis) when included in the diet at a level of 14.5% for pigs fed from 7 to 23 kg liveweight. McKinnon and Bowland (1977) concluded from their studies that CM (cv Tower) could be included in the diet at a level of 25% (complete replacement of SBM) in starter diets (5 - 20 kg liveweight) without significantly reducing average daily gain (ADG) or feed conversion efficiency (FCE), although average daily feed intake (ADF) was significantly reduced. In this experiment, the CM supplemented diet had a significantly lower apparent nitrogen and energy digestibility but a higher apparent biological value than did the SBM/CM mixture or the SBM

control diet. The overall apparent digestibility of the indispensable amino acids of the CM supplemented diet was significantly lower than the SBM/CM mixture or the SBM control diet. Castell (1977) however, observed significant reductions in ADG and FCE, but not in ADF among pigs from 10 to 32 kg liveweight fed a 7.5% CM (cv Tower) diet when compared to a SBM control diet. On the other hand, Salo (1980) reported that from 11 to 25 kg liveweight there were no significant differences in performance of pigs fed barley-skim milk-based diets supplemented with or without 10% CM. Ochetim *et al.* (1980a) suggested that no more than 20% of full-fat, crushed, cooked CM (cv Tower) should be used in the diet of early weaned pigs. Based on such inconclusive data, Bell and Aherne (1981) recommended that no more than 12% CM be included in starter pig diets.

B. Grower-finisher pigs

Due to the changing nutrient requirements of swine with body weight gain (NAS-NRC 1979), growing pigs (20-60 kg) are fed at different nutrient levels than are finisher pigs (60-90 kg). In some studies when pigs are fed from 20 to 90 kg liveweight, the same protein and energy levels are maintained thus making it impossible to separate the performance of pigs into grower and finisher phases of production (Aherne and Kennelly 1982). For this reason, only overall results (20-90 kg liveweight) should be reported for these types of studies.

Under restricted feeding conditions from 23 to 90 kg liveweight, Bell (1975) reported no significant performance differences for pigs fed diets in which RSM (cv Bronowski) replaced either 0, 25, 50, 75 or 100% of the SBM supplement, although there were trends for ADG and FCE to deteriorate as the level of RSM increased. The results of their digestibility studies indicated that as the dietary levels of RSM increased, the digestibility coefficients for protein and energy decreased. Bowland (1974) observed that when RSM (cv Bronowski) completely replaced the SBM supplement of diets fed to pigs from 6 to 100 kg liveweight, the performance of barrows fed a RSM supplemented diet was not significantly different to that of barrows fed a SBM control diet. However, gilts fed the RSM diet had lower ADG's, ADF's and FCE's than gilts fed the SBM control diet. The total replacement of SBM with CM (cv Tower) (12.5% in the diet) in the diets of pigs fed from 33 to 94 kg liveweight resulted in a 2.7% reduction in ADF and a 5.1% reduction in ADG when compared to the SBM control diet (Castell 1977). The supplementation of either 15% Tower or 15% Candle CM in the diets of pigs from 23 to 90 kg did not significantly reduce ADG, although FCE was lower ($P<0.05$) (Grandhi *et al.* 1979). Grandhi *et al.*(1980) observed that in one of two experiments, ADG and backfat were significantly reduced when CM (cv Tower) comprised 15% of the corn based diets fed from 23 to 90 kg compared to the SBM control diet. Narendran *et al.* (1981) reported no differences ($P<0.05$) in ADG, ADF,

FCE, backfat thickness and dressing percentage between pigs fed corn-SBM diets containing 0 to 25% CM (cv Tower).

Pigs fed barley-wheat-based diets from 23 to 90 kg liveweight supplemented solely with SBM, 15% Tower CM or 15% Candle CM had similar (P>0.05) ADG's and ADF's although pigs fed the 15% Tower CM diet had significantly lower FCE's than pigs fed the other two diets (Bell *et al.* 1981). The supplementation of the two CM diets with 0.15% lysine or 0.05% methionine improved the value of CM from 74 to 78% relative to the cost of SBM on a weight basis. These authors' suggested that the observed reduction in performance associated with CM supplemented diets may be partially due to a reduction in the energy digestibility of the diet, a marginal lysine deficiency and perhaps sufficient glucosinolate hydrolysis *in vivo* to affect metabolism.

Some experiments have shown that CM (cv Tower) can totally (Bowland 1975) or partially (McKinnon and Bowland 1977; Pearson and Bowland 1978) replace SBM in growing and finishing pig diets without having adverse effects on performance, while other studies have shown that complete (McKinnon and Bowland 1977) or partial (Kennelly *et al.*1978) substitution of SBM with CM (cv Tower) adversely affects pig performance. Aherne and Lewis (1978) and Kennelly *et al.*(1978) suggested that ADG and FCE of growing pigs from 20 to 60 kg liveweight are significantly reduced when CM is included in the diet at a level as low as 10%. Pigs fed SBM

supplemented diets grew significantly faster and required less crude protein per unit of gain than pigs from 23 to 67 kg liveweight fed barley-based diets containing 25% CM (cv Tower)(Singham and Lawrence 1979). Sauer *et al.*(1982) reported that in barrows fed purified diets from 50 to 60 kg liveweight, the true ileal availabilities of amino acids were higher for pigs fed the SBM supplemented diet than the CM supplemented diet. The true ileal availabilities for lysine, threonine and methionine were 88.3, 81.1 and 89.5%, respectively, for the SBM diet and 77.7, 72.7 and 84.5%, respectively, for the CM diet.

Studies involving the feeding value of CM for finisher pigs (60 to 90 kg liveweight) would suggest that CM can satisfactorily replace all of the protein supplement in finisher diets without adversley affecting performance or carcass quality (Bowland 1976; Aherne *et al.*1977; McKinnon and Bowland 1977; Aherne and Kennelly 1982).

Bell and Aherne (1981) suggested that for growing pigs (20 to 60 kg) CM should not replace more than one-half of the supplemental protein of the diet. However, when CM is fed during the entire grower-finisher phase (20 to 100 kg liveweight) or during the finisher phase (60 to 100 kg liveweight) then it may be included at the level of 10 to 15% in the diet without significantly reducing ADG, ADF or the carcass quality of the pigs (Aherne and Kennelly 1982).

C. Breeding swine

Recent research involving the effects of feeding CM to gilts and sows substantiated its use in female breeding stock rations. Studies by Bowland and Hardin (1973), Flipot and Dufour (1977), Lewis *et al.*(1978) and Lee *et al.*(1980) would indicate that CM can partially and/or completely replace the SBM supplement in breeding sow and gilt rations without causing a reduction in any aspect of sow reproductive performance.

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VII. CANOLA MEAL AS A PROTEIN SUPPLEMENT FOR STARTER PIGS.

A. Abstract

Two experiments were conducted to evaluate the replacement value of canola meal (CM) for soybean meal (SBM) in isoenergetic, isonitrogenous diets for starter pigs (8-25 kg liveweight). In Experiment One, 72 crossbred pigs (four weeks of age), equalized for sex and with an average initial weight of 8.4 kg, were randomly allotted on the basis of initial weight to one of three dietary treatments. CM was added to the diets replacing either 0, 50 or 100% of the SBM supplement (on an isonitrogenous basis). Pigs fed the SBM and the 50/50 SBM/CM diets grew significantly ($P<0.05$) faster than pigs fed the 100% CM supplemented diet. Pigs consumed more ($P<0.05$) of the SBM control diet than diets supplemented with either 50 or 100% CM. Feed conversion efficiency (FCE) was similar ($P>0.05$) for all treatments. In Experiment Two, 130 crossbred pigs (four weeks of age), equalized for sex and with an average initial weight of 6.9 kg, were randomly allotted to one of five dietary treatments on the basis of initial weight. Performance data between 7 and 15 kg liveweight and digestibility coefficients for protein and dry matter were determined for the diets in which CM replaced 0, 25, 50, 75 and 100% of the SBM supplement. Average daily gain (ADG) and average daily feed intake (ADF) were reduced ($P<0.05$) when CM replaced 75% and 50%, respectively, of the SBM supplement. The FCE and the

digestibility of protein and dry matter were not affected (P>0.05) by the level of CM in the diet. Regressions of ADG and ADF on percent CM in the diet for both trials indicated that for each one percent addition of CM to the diet, ADG and ADF were linearly reduced by 2 and 4 g, respectively. These two studies indicated that CM (approximately 17% in the diet) replaced 50% of the protein supplied by the SBM supplement without significantly affecting the growth rate or the FCE of starter pigs.

Key Words:STARTER PIG, CANOLA MEAL, SOYBEAN MEAL, PROTEIN SUPPLEMENT

B. Introduction

The improved value of canola meal (CM) (rapeseed meal containing less than 3 mg/g glucosinolates) as a livestock feed supplement has arisen through advances in breeding and processing of the seed. (Youngs *et al*.1981). Aherne and Kennelly (1982) reported that the nutritional value of CM in the diets for growing and finishing swine is well documented. However, the optimum replacement value of CM for soybean meal (SBM) in the diets of starter pigs has not yet been clearly established.

Some studies have shown that CM completely (Bowland 1975; Bowland *et al*.1975) or partially (McKinnon and Bowland 1977; Salo 1980) replaced the supplemental protein source in the diets of starter pigs without adversely affecting

performance, whereas other experiments indicated that complete (McKinnon and Bowland 1977) or partial (Castell 1977) substitution of the SBM supplement with CM caused a reduction in pig performance.

The lack of a concensus as to the optimum level of CM in the diets of starter pigs indicated that further research on this topic was required. The objective of these experiments was to determine the optimum replacement value of CM for SBM in the diet of starter pigs with an average initial weight of 8 kg.

C. Materials and Methods

Experiment One

Seventy-two crossbred (Yorkshire X Lacombe) pigs (four weeks of age), equalized for sex and with an average initial weight of 8.4 kg were randomly allotted to one of three dietary treatments on the basis of initial weight. The experimental diets were based on wheat, barley and oat groats and were formulated to meet or exceed National Academy of Sciences - National Research Council (NAS-NRC 1979) recommended levels of nutrient requirements (Table VII.1). The diets were formulated to be isoenergetic on a digestible energy basis and isonitrogenous on an as fed basis. The CM (cv Candle) was added to the diets replacing either 0, 50 or 100% of the SBM supplement (on an isonitrogenous basis) such that CM comprised either 0, 17 or 36% of the diet.

Pigs were housed in pairs (one barrow and one gilt) in 1.2 X 1.2 m slatted floor pens. The pigs were allowed *ad libitum* access to feed (steam-pelleted) and water. Pigs were weighed weekly and feed consumption was determined on a pen basis at the time of weighing. The environmental temperature was maintained at 21-23 °C throughout the 35 day study.

The percent crude protein, gross energy and dry matter in the diets were determined according to the Association of Official Analytical Chemists (AOAC 1975). Total dietary lysine levels were determined, following acid hydrolysis in 6 N HCL (Blackburn 1968), on a Beckman 121MB amino acid analyzer.

Analysis of variance of the data was performed according to Steele and Torrie (1980). Where appropriate, treatment means were tested for significance ($P<0.05$) using Student-Newman-Keuls (SNK) multiple range test when preceded by a significant F-test.

Experiment Two

One hundred and thirty crossbred (Yorkshire X Lacombe) pigs (four weeks of age), equalized for sex and with an average initial weight of 6.9 kg, were randomly allotted to one of five dietary treatments on the basis of initial weight. The experimental diets were based on wheat, barley and oat groats and were formulated according to procedures described in Experiment One (Table VII.2). The CM was added to the diets replacing either 0, 25, 50, 75 or 100% of the SBM supplement (on an isonitrogenous basis) such that CM

comprised 0, 9, 18, 27, or 36% of the diet. The diets containing CM were supplemented with Lysine-HCL to a level equal to the calculated available lysine level of the SBM control diet using fecal data of Sauer *et al.*(1981) and Sauer *et al.*(1982). Dysprosium ($DyCl\text{-}6H_20$) was added to each diet at a level of 10 ppm as an inert digestive indicator according to procedures by Kennelly *et al.*(1980).

Thirty-five pairs of pigs (one barrow and one gilt) were housed in 1.2 X 1.2 m slatted floor pens and 30 pairs of pigs were housed in 0.6 X 1.2 m flat decks with Tenderfoot flooring. The pigs were managed in the same way as in Experiment One.

The percent crude protein, dry matter, ether extract, gross energy and lysine levels of the feed and fecal samples were determined according to procedures described in Experiment One. The digestibility coefficients for dry matter and nitrogen were determined using the instrumental neutron activation analysis (INAA) procedure described by Kennelly *et al.*(1980). Fecal grab samples were collected from each pig on day 7 and day 28 of the test period.

The statistical analysis of variance of the data was determined according to procedures described in Experiment One.

D. Results and Discussion

Experiment One

Pigs fed the SBM and the 50/50 SBM/CM supplemented diets grew significantly faster than pigs fed the 100% CM supplemented diet (Table VII.3). Average daily feed intake (ADF) decreased ($P<0.05$) as the level of CM in the diet increased. Feed conversion efficiency (FCE) was not affected ($P>0.05$) by the level of CM in the diet (Table 3). The following regression analyses indicated that each one percent addition of CM to the diet resulted in a linear ($P<0.01$) decrease in average daily gain (ADG) and ADF of 2 and 4 g, respectively.

$$Y\ (ADG) = 0.441 - 0.002\ (\%CM)\quad r=-0.400$$

$$Y\ (ADF) = 0.848 - 0.004\ (\%CM)\quad r=-0.355$$

The results from this study indicated that CM replaced 50% of the SBM supplement without significantly reducing the growth rate or the FCE of young pigs.

Experiment Two

Pigs grew significantly slower when fed diets in which CM replaced 75% or more of the SBM supplement. The ADF was reduced ($P<0.05$) when 50% or more of the SBM supplement was substituted with CM. The FCE's were not significantly affected by the level of CM in the diet (Table VII.4). The following regression analyses indicated that each one percent addition of CM to the diet resulted in a linear ($P<0.001$) decrease in ADG and ADF of 2 and 4 g, respectively.

Y (ADG)= 0.306 - 0.002 (%CM) r=-0.533

Y (ADG)= 0.568 - 0.004 (%CM) r=-0.552

These results are in agreement with those obtained in Experiment One. When CM replaced 50% of the SBM supplement in the diets of starter pigs, no significant reductions in ADG or FCE were observed, although ADF was significantly lower.

The significant reduction in ADG when CM completely replaced SBM in starter pig diets does not agree with the results of Bowland (1975) and Bowland *et al.* (1975). McKinnon and Bowland (1977) also reported that CM (25% in the diet) completely replaced SBM in starter pig diets without significantly reducing ADG and FCE, although ADF was significantly reduced. They did report, however, that pigs gained significantly less weight during the growing period when fed a diet in which CM (20% in the diet) completely replaced the SBM supplement. On the other hand, Castell (1977) reported that starter pigs fed a diet containing 7.5% CM (cv Tower) gained significantly less weight and converted feed to body weight gain less efficiently than pigs fed a SBM control diet.

Although differences ($P<0.05$) in the digestibility of protein and dry matter of the diets were detected (Table VII.5), no consistent relationship ($P>0.05$) was observed between digestibility coefficients and the level of CM in the diet. Bowland (1975) found no significant differences in nitrogen digestibility of young pigs fed diets supplemented

with 100% SBM, 50/50 SBM/CM or 100% CM. McKinnon and Bowland (1977) however, reported that starter pigs consuming a diet supplemented with 100% CM exhibited a lower ($P<0.05$) nitrogen digestibility than pigs fed either a SBM or a 50/50 SBM/CM supplemented diet.

Neither the digestibility data nor the FCE values obtained in this experiment accounted for the reduction in pig performance associated with an increase in the level of CM in the diet. Adjustment of ADG for the observed differences in ADF removed ($P>0.05$) the treatment differences in ADG between the CM and SBM supplemented diets. The supplementation of Lysine-HCL on an available lysine basis (0.94%) did not improve the ADF of starter pigs in Experiment Two. Aherne and Nielsen (1982) failed to improve the ADF of starter pigs (7-19 kg liveweight) fed SBM supplemented diets by the addition of L-lysine HCL to diets containing 0.87 or 1.17% available lysine and 18 or 20% crude protein. It would therefore appear that the reduction in feed intake of diets containing CM is not due to a dietary deficiency of lysine nor to a reduction in the utilization of nitrogen from CM.

The progressive decrease in feed intake as the level of CM in the diet increased appeared to have accounted for the observed differences in growth rate between pigs fed the CM and SBM supplemented diets. Possible reasons for the reduction in feed intake of diets containing CM may be due to the influence of glucosinolates on thyroid function

(McKinnon and Bowland 1979; Ochetim *et al.* 1980a, 1980b) and/or the palatability of the meal (Singham *et al.* 1979; Chubb 1982; McIntosh and Aherne 1983).

The results of these two experiments indicated CM (16.6-18% in the diet) safely replaced up to 50% of the SBM supplement without significantly reducing the growth rate or FCE of starter pigs fed from 8 to 25 kg liveweight.

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Table VII.1. Formulation and chemical composition of diets supplemented with soybean meal (SBM) and canola meal (CM) (Experiment 1).

Diets:	100%SBM	50%SBM 50%CM	100%CM
Level of CM in Diet (%):	0	16.6	35.5
Criteria			
Ingredients (%):			
Wheat	25.0	25.0	25.0
Barley	22.6	16.8	10.5
Oat groats	20.0	20.0	20.0
Soybean meal (45.7% C.P.[1])	25.4	13.6	---
Canola meal (36.0% C.P.)	----	16.6	35.5
Blended animal fat	3.0	4.0	5.0
Iodized salt	0.5	0.5	0.5
Calcium phosphate	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0
Starter premix[2]	1.0	1.0	1.0
Chemical Analysis[3]:			
Dry matter (%)	89.8	90.2	90.1
Crude protein (%)	21.4	21.9	22.0
Lysine (%)	1.06	1.03	0.99
Gross energy (MJ/kg)	16.9	16.9	17.0
Digestible energy (MJ/kg)[4]	14.6	14.4	14.0

[1] CP, crude protein.

[2] Starter premix provided the following per kg of diet: 120.0 mg zinc, 12.0 mg manganese, 150.0 mg iron, 12.0 mg copper, 0.1 mg selenium, 5000 IU vitamin A, 700 IU vitamin D-3, 23 IU vitamin E, 12 mg riboflavin, 45 mg niacin, 25 mg calcium pantothenate, 30 *u*g vitamin B-12, 500 mg choline chloride, 275 mg ASP250.

[3] Determined values reported on an as-fed basis unless otherwise indicated.

[4] Calculated according to NAS-NRC (1979) recommendations for the digestible energy of feed ingredients commonly used in starter pig rations.

Table VII.2. Formulation and chemical composition of diets supplemented with soybean meal (SBM) and canola meal (CM) (Experiment 2).

Diets:	100%SBM	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM
Level of CM in diet (%):	0	9	18	27	36
Criteria					
Ingredients (%):					
Wheat	25.0	25.0	25.0	25.0	25.0
Barley	19.9	16.1	12.6	8.9	4.6
Oat groats	20.0	20.0	20.0	20.0	20.0
Soybean meal (47.1% CP[1])	25.2	18.7	12.0	5.7	----
Canola meal (36.7% CP)	----	9.0	18.0	27.0	36.0
Blended animal fat	1.5	2.8	4.0	5.0	6.0
Iodized salt	0.5	0.5	0.5	0.5	0.5
Calcium phosphate	1.5	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0	1.0
L-lysine. HCL (78%)[2]	----	0.05	0.1	0.15	0.17
Starter premix[3]	5.4	5.4	5.4	5.4	5.4
Chemical Analysis[4]:					
Dry matter (%)	89.7	89.9	90.5	90.4	90.4
Crude protein (%)	19.8	20.2	20.5	21.3	20.8
Lysine (%)	0.99	1.04	1.07	1.12	1.08
Gross energy (MJ/kg)	16.74	17.11	17.61	17.95	18.07
Ether extract (%)	4.1	6.0	6.0	7.2	8.4
Digestible energy (MJ/kg)[5]	14.43	14.43	14.39	14.35	14.31

[1]CP, crude protein.

[2]Calculated according to Sauer et al (1981) and Sauer et al (1982) for fecal lysine availabilities: wheat, 79%; barley, 74%; SBM, 88%; CM, 78%.

[3]Starter premix provided the following per kg of diet: 120.0 mg zinc, 12.0 mg manganese, 150.0 mg iron, 12.0 mg copper, 0.1 mg selenium, 5000 IU vitamin A, 700 IU vitamin D-3, 23 IU vitamin E, 12 mg riboflavin, 45 mg niacin, 25 mg calcium pantothenate, 30 ug vitamin B-12, 500 mg choline chloride, 275 mg ASP250, 10 mg dysprosium.

[4]Determined values reported on an as-fed basis unless otherwise indicated.

[5]Calculated according to NAS-NRC (1979) recommendations for the digestible energy of feed ingredients commonly used in starter pig rations.

Table VII.3. The average performance of pigs fed diets supplemented with soybean meal (SBM) and canola meal (CM) (Experiment 1).[2]

Diets:	100%SBM	50%SBM 50%CM	100%CM	SE[1]
Level of CM in diet (%)	0	16.6	35.5	
Criteria				
Performance[3]:				
Initial wt (kg)	8.4	8.4	8.4	0.34
Final wt (kg)	26.0a	24.4a	21.8b	0.80
Daily gain (g)	503a	459a	383b	15.5
Daily feed (g)	997a	899b	786c	29.6
Feed:Gain	1.99	1.96	2.06	0.05

[1]SE, standard error of the mean.

[2]a-c, means within the same row with the same or no letter are not significantly different ($P<0.05$).

[3]24 pigs per dietary treatment (12 replications of 2 pigs).

Table VII.4. The average performance of pigs fed diets supplemented with soybean meal (SBM) and canola meal (CM) (Experiment 2).[2]

Diets:	100%SBM	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[1]
Level of CM in diet (%)	0	9	18	27	36	
Criteria						
Performance[3]:						
Initial wt. (kg)	6.9	6.9	6.9	6.9	6.9	0.23
Final wt. (kg)	15.2a	15.3a	14.4ab	13.5bc	13.1c	0.45
Daily gain (g)	295a	301a	269ab	238bc	223c	12.4
Daily feed (g)	570a	537ab	492bc	447c	433c	21.5
Feed:gain	1.94	1.79	1.85	1.89	1.98	0.05

[1]SE, Standard error of the mean.

[2]a-c, means within rows with the same or no letter are not significantly different ($P<0.05$).

[3]26 pigs per dietary treatment (13 replicates of 2 pigs).

Table VII.5. Digestibility coefficients for dry matter (DM) and nitrogen (N) of starter pig diets supplemented with soybean meal (SBM) and canola meal (CM) (Experiment 2).[2]

Diets:	100%SBM	75%SBM 25%CM	50%SBM 50%CM	25%SBM 75%CM	100%CM	SE[1]
Level of CM in diet (%)	0	9	18	27	36	
Criteria						
Digestibilities[3] (%):						
Day 7 DM	74.9c	71.2ab	74.2c	69.2a	73.2bc	0.76
Day 7 N	68.1b	63.4a	70.0b	66.9ab	70.1b	0.76
Day 28 DM	76.0c	72.8ab	75.0bc	70.6a	74.9bc	1.44
Day 28 N	70.9b	67.4a	72.4b	70.5b	73.4b	1.11

[1]SE, standard error of the mean.

[2]a-c, means within the same row with the same or no letter are not significantly different (P<0.05).

[3]26 pigs per dietary treatment (13 replications of 2 pigs).

VIII. UTILIZATION OF NITROGEN AND OF AMINO ACIDS IN CANOLA MEAL BY STARTER PIGS.

A. Abstract

The utilization of nitrogen (N) and amino acids (AA) was determined in canola meal (CM) supplemented diets formulated to contain 7.8, 13.2, 17.0 and 23.8% crude protein. Eight crossbred barrows with an initial weight of 9.0 ± 0.9 kg were allotted to one of four isoenergetic diets on the basis of initial weight in a replicated 4 X 4 Latin square design. Diets were formulated by varying the amounts of cornstarch and CM. Endogenous levels of N and AA in feces were determined by the regression analysis method. The apparent digestibility coefficients for dry matter and energy decreased linearly ($P<0.05$) as the level of protein in the diet increased. There was a linear ($P<0.05$) increase in the apparent N digestibility and the apparent net protein utilization (NPU) as the level of dietary protein increased. The apparent and true N balance significantly ($P<0.05$) increased with increasing protein levels. True N digestion, biological value (BV) and NPU were not significantly affected by the level of protein in the diet. The apparent availabilities among all the indispensable and dispensable AA, except proline, linearly ($P<0.05$) and/or quadratically ($P<0.05$) increased as the level of protein in the diet increased. At the 7.8% crude protein level, methionine, isoleucine and threonine had the lowest apparent

availabilities among the indispensable AA. Tyrosine, alanine and aspartic acid had the lowest apparent availabilities among the dispensable AA. The true availabilities among all the AA were not affected (P>0.05) by treatment. The estimate of true BV and NPU for the starter pigs fed CM supplemented diets at graded protein levels was 70.5 and 57.7%, respectively.

Key Words: STARTER PIG, CANOLA MEAL, NITROGEN BALANCE, AMINO ACIDS

B. Introduction

Previous studies for determining the protein quality and amino acid (AA) availability of canola meal (CM) and/or soybean meal (SBM) for swine have been primarily performed on growing-finishing animals (Armstrong and Mitchell 1955; Sauer *et al.* 1982). The protein quality and AA availability of CM for young pigs has received much less attention. Bowland (1975) reported no significant differences in the apparent nitrogen (N) utilization whereas McKinnon and Bowland (1977) observed differences in apparent digestibility coefficients (ADC) for N and in biological value (BV) when CM completely replaced the SBM supplement in grain-based starter pig diets. McKinnon and Bowland (1977) also stated that the ADC for energy and for the indispensable AA for a 100% CM supplemented diet were significantly lower than for pigs fed a diet partially

substituted with CM or a SBM control diet. McIntosh and Aherne (1983), however, did not observe a significant reduction in the ADC for N as the level of CM in grain-based diets of starter pigs increased from 0 to 36%.

The objectives of this experiment were (1) to determine the digestion, absorption and retention of the protein (N x 6.25) derived from CM and (2) to determine the availability of AA of CM when included in isoenergetic starter pig diets at graded levels.

C. Materials and Methods

Eight crossbred (Yorkshire x Lacombe) barrows, four from each of two litters, with an average initial weight of 9.0± 0.9 kg were assigned to a 36 day study. The four experimental diets were formulated to meet or exceed National Academy of Sciences-National Research Council (NAS-NRC 1979) recommended levels of nutrient requirements, with the exception of protein. Protein in the diet was supplied by CM replacing cornstarch at levels of 7.8, 13.2, 17.0 and 23.8% (Table VIII.1). The diets were balanced for digestible energy by the addition of corn oil. Dextrose was included at a level of 10% to potentially improve palatability.

Pigs were fed the diets in a mash form at a level of approximately 4% of body weight in three equal amounts at 0800, 1300 and 1800 h. Water was supplied *ad libitum* from a low pressure drinking nipple. The barrows were individually

confined in 0.5 X 1.0 m metabolic crates which permitted separation and quantitative collection of feces and urine. The environmental temperature of the unit was maintained at 23°C throughout the experiment.

Animals were allotted to one of four dietary treatments on the basis of initial weight in a replicated 4 X 4 Latin square design. Each of the four test periods lasted nine days. The pigs were allowed to adapt to each diet for the first five days of each period and feces and urine were collected for the next four days.

Urine was collected daily in 20 l plastic pails containing 35 ml of 0.1 N HCL, mixed thoroughly and a 1% aliquot was taken. Urine and fecal samples were kept frozen until analyzed. At the conclusion of the experiment, the fecal samples were freeze-dried, weighed, ground in a Wiley mill through a 1 mm mesh and throughly mixed before samples were taken for analysis.

Analysis for protein (N x 6.25), dry matter, ash, ether extract, and energy content were carried out according to the Association of Analytical Chemists (AOAC 1975) methods. Acid detergent fibre and neutral detergent fibre analysis of feed and feces were determined according to procedures described by Goering and Van Soest (1970). The AA levels of feed and feces were determined, following acid hydrolysis in 6 N HCL (Blackburn 1968), on a a Beckman 121MB amino acid analyzer. Tryptophan and cystine levels were not determined in this study.

Data were analyzed by the least-squares analysis of variance for unequal numbers according to Harvey (1975). Sources of variation included replication (n=2), treatments (n=4) and period (n=4). Where appropriate, means were compared for significance ($P<0.05$) using the Student-Newman-Keuls (SNK) multiple range test when preceded by a significant F-test (Steele and Torrie 1980). For each variable an additional analysis was computed in which the treatment sum of squares (SS) was subdivided into linear, quadratic and cubic response curves (RC) and tested for significance ($P<0.05$) using Duncan's multiple range test (Steele and Torrie 1980).

The term fecal availability of AA in this study refered to the portion of AA present in a dietary protein which are potentially available for growth, development and/or maintenance, measured by the difference of the AA consumed and void in the feces. The fecal method, however, does not take into account the modifying action of the microflora in the hindgut on AA metabolism as does the ileal method (Sauer *et al.*1982). Estimates of metabolic fecal AA and N were determined according to the regression method (Mitchell 1924).

D. Results

The chemical analyses of the diets are presented in Table's VIII.1 and VIII.4. The pigs gained an average of 168± 24 g/day in liveweight over the 36 day trial. Two pigs

incurred digestive upsets near the end of the trial and were taken off test. The ADC for dry matter (DM) and energy linearly ($P<0.05$) decreased as the level of protein in the diet increased (Table VIII.2). The ADC for N and the apparent N balance linearly ($P<0.05$) increased with increased levels of protein (Table VIII.3). The apparent BV was not significantly affected by the level of protein in the diet, but tended ($P<0.055$) to improve as the level of protein in the diet increased. There was a linear ($P<0.05$) increase in the apparent NPU as the protein level in the diet increased.

The estimation of 1.65 g of metabolic fecal N (MFN) per kg of DM consumed was determined using individual data values from regression analysis to 0% crude protein (CP) intake (Fig.VIII.1). The estimation of 0.025 g of endogenous urinary N (EUN) per kg of body weight$^{.5}$ (MBW) was similarly determined to 0% true N absorbed (TNA) (Fig.VIII.2).

$$Y\ (MFN) = 1.645 + 0.291\ (\%CP)\quad r=0.922$$

$$Y\ (EUN) = 0.025 + 0.299\ (TNA)\quad r=0.970$$

The true N balance increased linearly ($P<0.05$) with increased protein level. The level of protein intake had no significant effect on true N digestion, true BV or true NPU. The coefficients for true BV and NPU were 70.5 and 57.7%, respectively.

With the exception of proline, the apparent availabilities of all the indispensable and dispensable AA linearly ($P<0.05$) increased as the dietary protein level

increased (Table VIII.5). The apparent availabilities of all the AA , except valine, alanine, proline and serine,increased quadratically ($P<0.05$) with increasing levels of dietary protein. At the 7.8% CP level, methionine, isoleucine and threonine had the lowest apparent availabilities among the indispensable AA. Tyrosine, alanine and aspartic acid had the lowest apparent availabilities among the dispensable AA. No treatment differences ($P>0.05$) were detected for the true availabilities of the AA measured (Table VIII.6).

E. Discussion

The observed differences among the ADC for DM and energy were most probably due to the increase in CM (high in fibre) at the expense of cornstarch which is low in fibre and high in digestible energy (DE). Taverner *et al.*(1981) reported negative correlations of fibre content to the digestibility of DM and energy for cereal-based diets fed to growing pigs.

The extrapolated value of 1.645 g of MFN per kg of DM consumed falls within the range of values (i.e. 0.63 to 2.00 g) reported by Armstrong and Mitchell (1955) for growing pigs fed a variety of diets and by Gjefsen and Opstvedt (1980) (1.27 and 1.89 g) for starter pigs fed a dry skim milk and a fishmeal-whey diet, respectively. The amount of fecal N excreted in their study remained fairly constant whereas in the present study the fecal N output increased as

the level of protein in the diet increased. This response may again be due to influence of the fibre level from CM. Sauer *et al.*(1977) and Bergner (1982) reported that increasing the fibre content of the diet from approximately 5 to 15% increased microbial fermentation and the amounts of fecal N and AA in growing and young pigs, respectively.

The extrapolated value of 25.1 mg of EUN per kg of MBW falls below that of Armstrong and Mitchell (1955) (133 mg), Carr *et al.*(1977) (150 mg), Wilson and Leibholz (1979) (141 mg) and Gjefsen and Opstvedt (1980) (103 mg). This may be partially explained by the different set of nutritional, environmental and experimental conditions under which studies of this nature were conducted. Armstrong and Mitchell (1955) and Gjefsen and Opstvedt (1980), for example, did not utilize data from protein levels exceeding 16% and 18%, respectively, in their statistical analysis of EUN. The EUN values reported by Carr *et al.*(1977) and Wilson and Leibholz (1979) were obtained by feeding protein free diets. Sauer *et al.*(1977) and Taverner *et al.*(1981) noted the concern of many nutritionists that the values obtained for MFN and EUN by feeding protein free diets may overestimate the actual amounts of N lost daily compared to those obtained with animals fed diets that support both maintenance and growth. Other factors such as body size and DM intake; source, density and ratios of dietary energy and protein; species, sex and physiological age of the animals; and the experimental, technical and statistical procedures

employed can have a pronounced affect on the determination of N and AA utilization (Forbes and Yohe 1954; Munro 1964; Mason and Palmer 1973; Sauer *et al.* 1982).

It is generally accepted that under standardized conditions, as the level of protein in the diet increases, the apparent N digestibility, BV and NPU and AA availability increases, the true BV and NPU decreases and the true N digestibility and AA availability remains constant. (Eggum 1973). In the present study there was a linear increase ($P<0.05$) in the apparent digestibility of N and the apparent NPU. There was also a significant linear and quadratic increase in the apparent AA availability as the level of dietary protein increased. The true N digestibility and AA availability also remained constant over the graded protein levels tested. However, the true BV and NPU did not significantly change with increasing protein levels. Diets were not equalized for fibre so as to give a realistic estimation of the BV of CM for starter pigs. The calculated values for the true BV and NPU of CM for starter pigs were 70.5 and 57.7%, respectively.

Comparison betweens the highest and lowest apparent fecal AA availabilities obtained by Sauer *et al.*(1982) for CM (cv Candle) supplemented diets (10% CP) fed to growing pigs and at the 13.2% CP level in this study are almost identical. Among the indispensable AA, isoleucine (75.2% vs 75.8%) and valine (74.5% vs 77.5%) had the lowest and arginine (86.3% vs 87.5%), histidine (86.0% vs 90.4%) and

lysine (79.6% vs 79.6%) had the highest apparent availabilities of AA in this study compared to that of Sauer *et al.*(1982). Among the dispensable AA in both studies the ranking of availabilities was identical, with tryrosine (65.2% vs 74.3%) and alanine (74.3% vs 81.6%) having the lowest and glutamic acid (87.6% vs 90.0%) and proline (83.5% vs 87.1%) the highest availabilities of AA in this study compared to that of Sauer *et al.*(1982).

It has been suggested that the fecal method for evaluating protein quality may not be as reliable as the ileal method due to endogenous secretions into the digestive tract and the effect of the microorganisms in the caecum and colon (Taverner *et al.* 1981; Sauer *et al.*1980). Mason and Palmer (1973) stated that the amount of N excreted in the feces was primarily determined by the level of bacterial activity in the hindgut, which in turn was influenced by the type and pretreatment of the carbohydrates in the diet. Comparative studies of the fecal and ileal methods to determine the rate of disappearance of N and AA in the large intestine have shown that the fecal method may overestimate N utilization and certain AA availabilities (Sauer *et al.1981; Sauer et al.*1982).

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Table VIII.1. Formulation and chemical composition of diets containing four levels of canola meal (CM).

Level of crude protein (%):	7.8	13.2	17.0	23.8
Criteria				
Ingredients (%):				
Canola meal (36.5% C.P.[1])	16.4	32.9	49.3	65.8
Corn Starch	69.6	51.1	32.7	14.3
Dextrose	10.0	10.0	10.0	10.0
Corn Oil	---	2.0	4.0	6.0
Calcium phosphate	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0
Iodized salt	0.5	0.5	0.5	0.5
Starter premix[2]	1.0	1.0	1.0	1.0
Chemical Analysis[3]:				
Dry matter (%)	89.4	89.6	90.1	90.9
Gross energy (MJ/kg)	15.19	15.95	16.94	17.84
Digestible energy (MJ/kg)	13.42	13.49	13.84	13.94
Metabolizable energy (MJ/kg)[4]	13.27	13.27	13.58	13.60
Ether extract (%)	0.76	2.12	4.61	7.08
Acid detergent fibre (%)	4.84	7.65	10.34	14.19
Neutral detergent fibre (%)	7.35	12.50	15.42	18.96
Ash (%)	4.59	4.86	5.57	7.38

[1]CP, crude protein.

[2]Starter premix provided the following per kg of diet: 120.0 mg zinc, 12.0 mg manganese, 150.0 mg iron, 12.0 mg copper, 0.1 mg sodium, 0.12 mg cobalt, 0.04 mg magnesium, 0.1 mg selenium, 193.0 mg calcium, 5000 IU vitamin A, 500 IU vitamin D-3, 23 IU vitamin E, 4.0 mg vitamin K, 12 mg riboflavin, 45 mg niacin, 25 mg calcium pantothenate, 30 ug vitamin B-12, 500 mg choline chloride, 0.2 mg biotin, 1.5 mg pyridoxine, 1.0 mg folic acid, 0.15 g ethoxyquin, 275 mg ASP 250.

[3]Determined values reported on an as-fed basis unless otherwise indicated.

[4]Calculated according to May and Nelson (1972): Y=7.00(X) + 6.56 where Y= total gross energy of urine; and X= total g N in the urine.

Table VIII.2. Apparent digestibility coefficients for diets containing four levels of canola meal (CM) fed to starter pigs[3].

Level of crude protein (%)	7.8	13.2	17.0	23.8	SE[1]	RC[2]
Criteria						
Digestibilities (%):						
Dry matter	88.9a	85.1b	81.9c	77.5d	0.53	L
Ether extract	72.1a	82.1b	87.4c	90.3c	1.26	L,Q
Ash	52.5	47.7	48.7	51.1	1.73	NS
Acid detergent fibre	39.1	39.0	40.4	45.3	2.11	NS
Neutral detergent fibre	58.8	64.9	63.1	61.1	1.52	Q
Digestible energy	88.4a	84.3b	81.6c	78.0d	0.53	L
Metabolizable energy	87.3a	83.1b	80.0c	76.1d	0.54	L

[1]SE, standard error of the mean.

[2]RC, significance ($P<0.05$) of the linear (L) or quadratic (Q) responce curves (RC) to dietary levels of protein (NS being not significant).

[3]a-d, means within the same row with the same or no letter are not significantly different ($P<0.05$).

Table VIII.3. Daily utilization of nitrogen (N) by starter pigs fed diets containing four levels of canola meal (CM).[6]

Level of crude protein (%):	7.8	13.2	17.0	23.8	SE[1]	RC[2]
Criteria						
Measurements:						
N intake (g/day)	5.8a	9.8b	10.3c	17.5d	0.18	L
N in feces (g/day)	1.8a	2.4b	3.1c	3.9d	0.12	L
N in urine (g/day)	1.6a	2.6b	3.2c	4.6d	0.06	L
Fecal N (mg) per kg DM intake	4.2a	5.8b	7.5c	9.3d	0.26	L
N in urine (mg) per kg MBW[3]	236a	383b	483c	690d	11.2	L
Determinations:						
Apparent N digestion (%)	69.8a	75.6b	75.2b	77.7b	1.01	L
Apparent N absorption (g/day)	4.1a	7.4b	9.4c	13.7d	0.18	L
Apparent N retention (g/day)	2.5a	4.8b	6.2c	9.1d	0.20	L
Apparent BV (%)[4]	61.0	65.5	65.7	66.3	1.44	NS
Apparent NPU (%)[5]	42.7a	49.5b	49.5b	51.6b	1.49	L
True N digestion (%)	81.6	82.5	80.7	81.6	1.01	NS
True N absorption (g/day)	4.7a	8.1b	10.1c	14.3d	0.18	L
True N retention (g/day)	3.3a	5.7b	7.1c	9.9d	0.20	L
True BV (%)	70.2	70.5	69.7	69.1	1.20	NS
True NPU (%)	57.3	58.2	56.3	56.5	1.49	NS

[1]SE, standard error of the mean.

[2]RC, significance ($P<0.05$) of the linear (L) or quadratic (Q) responce curves (RC) to the dietary level of protein (NS being not significant).

[3]MBW, body weight$^{.75}$

[4]Biological Value, N retained expressed as a percentage of the N absorbed.

[5]Net Protein Utilization, N retention expressed as a percentage of the gross N intake.

[6]a-d, means within the same row with the same or no letter are significantly different ($P<0.05$).

Table VIII.4. Amino acid (AA) composition of diets containing four levels of canola meal (CM).

Level of crude protein (%)	7.8	13.2	17.0	23.8
Criteria				
Indispensable AA's (%):				
Arginine	0.46	0.80	1.04	1.45
Histidine	0.22	0.38	0.49	0.68
Isoleucine	0.32	0.55	0.70	0.97
Leucine	0.60	1.03	1.30	1.79
Lysine	0.44	0.75	0.98	1.34
Methionine	0.12	0.23	0.30	0.44
Phenylalanine	0.32	0.54	0.68	0.93
Threonine	0.35	0.62	0.80	1.08
Valine	0.41	0.70	0.91	1.24
Dispensable AA's (%):				
Alanine	0.38	0.63	0.81	1.12
Aspartic Acid	0.68	1.13	1.44	1.97
Glutamic Acid	1.49	2.50	3.18	4.39
Glycine	0.41	0.72	0.92	1.27
Proline	0.52	0.87	1.12	1.52
Serine	0.38	0.64	0.83	1.16
Tyrosine	0.15	0.27	0.36	0.53
AA Nitrogen recovery[1]	90.8	91.2	91.5	89.8

[1]Nitrogen contained in amino acids expressed as a percentage of total nitrogen in diets.

Table VIII.5. Apparent fecal availabilities of amino acids (AA) of diets containing four levels of canola meal (CM) fed to starter pigs.[4]

Level of crude protein (%)	7.8	13.2	17.0	23.8	SE[1]	RC[2]
Criteria						
Indispensable AA's (%):						
Arginine	81.7a	86.3b	86.4b	87.5b	0.56	L,Q
Histidine	82.3a	86.0b	85.6b	86.7b	0.59	L,Q
Isoleucine	68.9a	75.2b	74.4b	76.3b	0.95	L,Q
Leucine	70.1a	76.6b	76.0b	77.7b	0.92	L,Q
Lysine	74.4a	79.6b	79.6b	80.4b	0.87	L,Q
Methionine	65.5a	76.3b	77.1b	80.1b	1.28	L,Q
Phenylalanine	69.5a	75.8b	75.1b	76.8b	0.90	L,Q
Threonine	69.1a	76.4b	75.4b	76.7b	0.95	L,Q
Valine	71.5a	74.5ab	77.4b	79.0b	1.57	L
Dispensable AA's (%):						
Alanine	68.6a	74.3b	74.2b	76.2b	1.09	L
Aspartic Acid	68.7a	74.9b	74.6b	76.1b	0.97	L,Q
Glutamic Acid	83.9a	87.6b	87.0b	87.8b	0.46	L,Q
Glycine	74.6a	79.9b	80.0b	81.4b	0.84	L,Q
Proline	79.8	83.5	82.1	81.2	1.25	NS
Serine	73.0a	77.9b	78.3b	80.0b	0.82	L
Tyrosine	52.0a	65.2b	67.0bc	70.7c	0.82	L,Q
AA Nitrogen recovery[3]	73.5	73.4	73.6	75.0	0.41	

[1]SE, standard error of the mean.

[2]RC, significance ($P<0.05$) of the linear (L) or quadratic (Q) responce curves (RC) to dietary level of protein (NS being not significant).

[3]Nitrogen contained in amino acids expressed as a percentage of total nitrogen in the feces.

[4]a-b, means within the same row with the same or no letter are not significantly different ($P<0.05$).

Table VIII.6. True fecal availabilities of amino acids (AA) of diets containing four levels of canola meal (CM) fed to starter pigs.[2]

Level of crude protein (%)	7.8	13.2	17.0	23.8	SE[1]
Criteria					
Indispensable AA's (%):					
Arginine	88.7	90.4	89.4	89.6	0.67
Histidine	87.9	89.3	88.1	88.5	0.66
Isoleucine	79.6	81.6	79.5	80.1	1.13
Leucine	81.5	83.3	81.4	81.7	1.06
Lysine	82.0	84.2	82.8	82.8	1.22
Methionine	81.0	84.0	83.3	84.4	1.70
Phenylalanine	81.6	83.2	81.1	81.3	1.23
Threonine	79.0	82.2	79.9	80.1	1.16
Valine	84.3	82.0	83.0	83.1	1.41
Dispensable AA's (%):					
Alanine	80.7	81.9	80.1	80.6	1.27
Aspartic Acid	81.0	82.5	80.7	80.7	1.19
Glutamic Acid	89.7	91.1	89.8	89.9	0.58
Glycine	84.1	85.4	84.4	84.6	0.95
Proline	81.5	84.7	84.0	82.2	1.44
Serine	83.2	84.0	83.0	83.5	1.00
Tyrosine	71.3	76.1	75.2	76.3	1.65

[1]SE, standard error of the mean.

[2]Means within the same row with the same or no letter are not significantly different ($P<0.05$).

[3]Neither the linear, quadratic nor cubic responce curves to dietary levels of protein were significant ($P<0.05$) for any of the AA's measured.

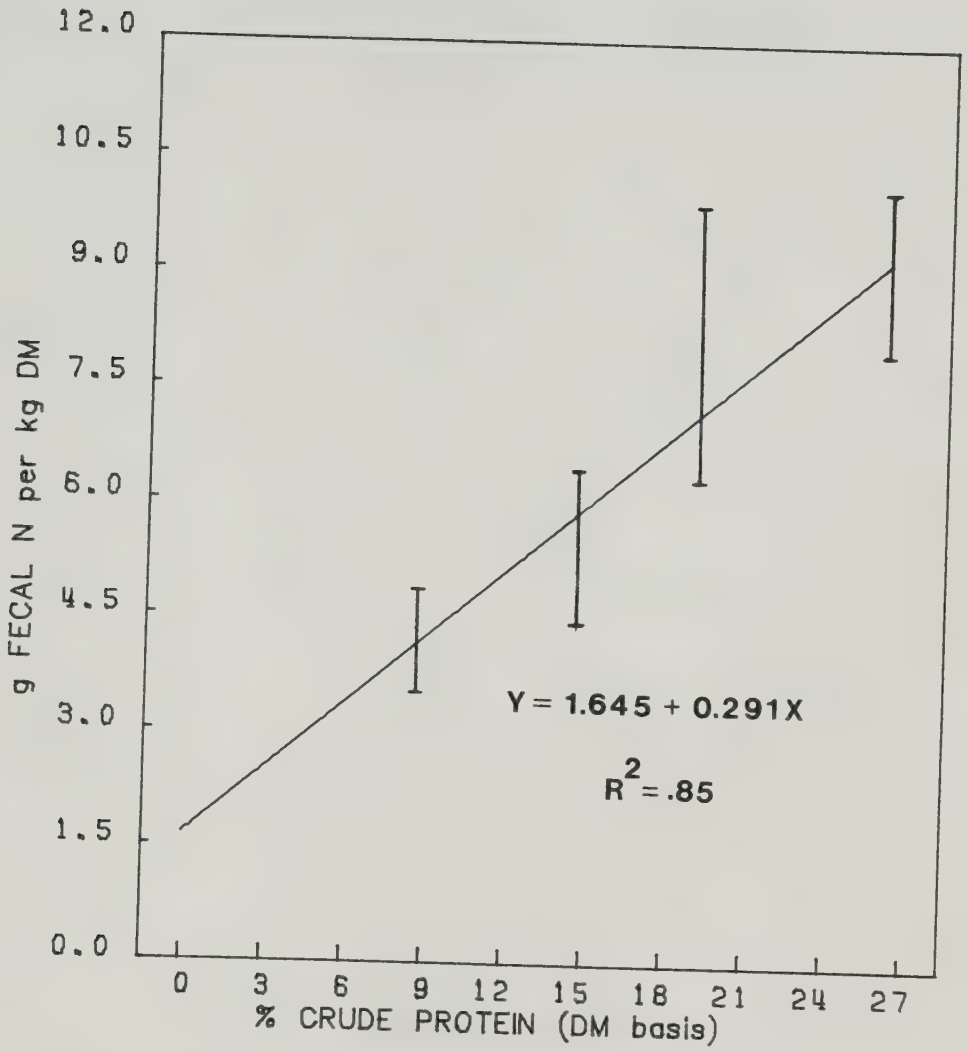

Figure VIII.1 Determination of metabolic fecal nitrogen (MFN) by the regression method.

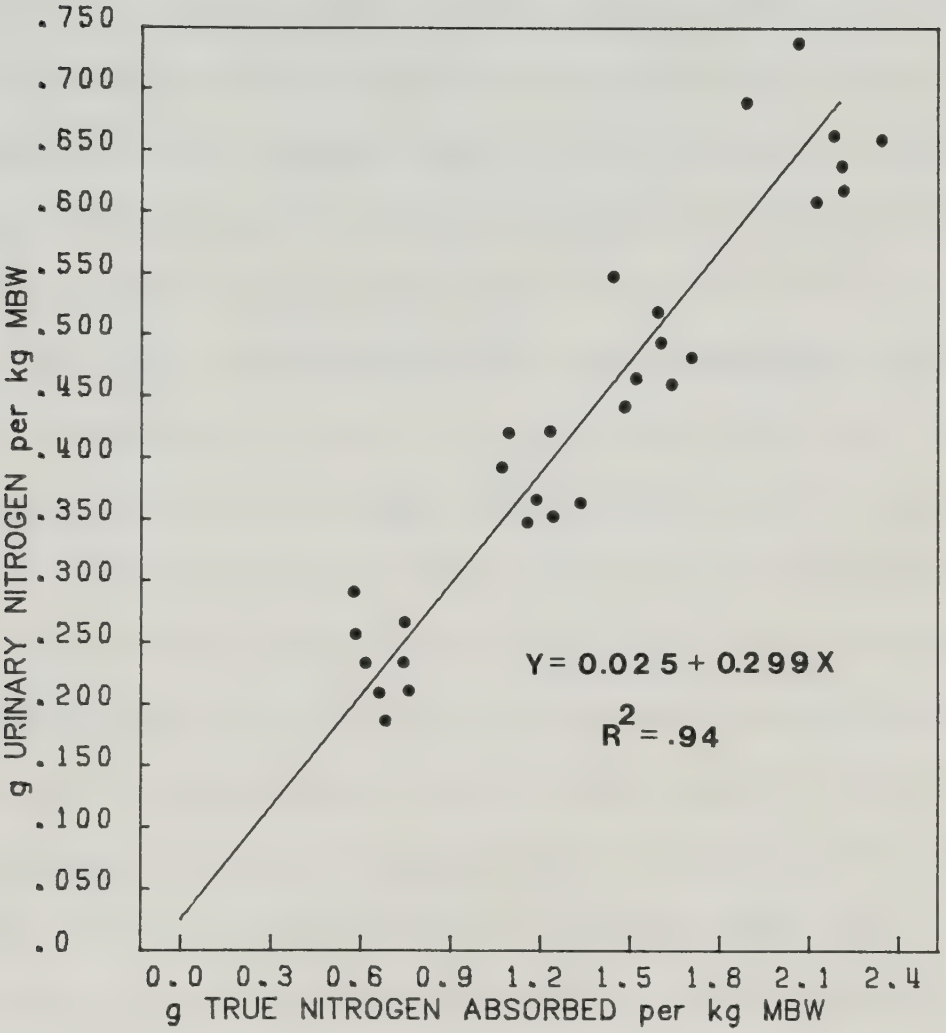

Figure VIII.2 Determinaton of endogenous urinary nitrogen (EUN) by the regression method.

IX. SELECTION PREFERENCES OF STARTER PIGS FED CANOLA MEAL AND SOYBEAN MEAL SUPPLEMENTED DIETS.

A. Abstract

Three experiments were conducted to determine the selection preferences of starter pigs from 7 to 27 kg liveweight for barley-wheat-oat groat-based diets supplemented with soybean meal (SBM) and canola meal (CM). In Experiment One, 16 starter pigs were offered a choice between a SBM control diet and any one of four isonitrogenous, isoenergetic CM supplemented diets containing either 5, 10, 15 or 20% CM. Pigs fed from five to nine weeks of age consumed two and one-half to seven times more of the SBM control diet than diets containing 5 to 20% CM, respectively. When given a choice, pigs consumed significantly ($P<0.05$) less of the diet containing 5% CM than the SBM control diet and significantly reduced their consumption of the CM supplemented diets as the level of CM in the diet increased to 20%. In Experiment Two, 12 starter pigs were given different periods of time to adapt to a 10% CM diet (4-24 days) and were subsequently given a choice between the 10% CM diet and a SBM control diet. Duration of the adaptation period to a 10% CM diet had no effect ($P>0.05$) on the subsequent selection preference of starter pigs fed a SBM or CM supplemented diet. When given a choice, pigs consumed approximately three and one-half times as much of a SBM control diet than a diet containing 10% CM, with or

without prior adaptation to the 10% CM diet. In Experiment Three, the influence of supplementary monosodium glutamate (0.15%), dextrose (10%) and corn oil (4-5%) on the consumption of diets in which CM replaced 50 or 100% of the protein supplied by the SBM supplement was studied. No significant differences in feed intake or pig performance were attributed to the addition of these flavour additives to diets containing CM. Pigs fed a SBM control diet and a 50/50 SBM/CM mixture containing dextrose grew faster($P<0.05$) than pigs fed the 100% CM supplemented diets with or without the flavour additives. Pigs fed the 50/50 SBM/CM diet containing dextrose consumed more ($P<0.05$) feed than pigs fed the 100% CM supplemented diet with or without the flavour additives. Feed conversion efficiencies were similar ($P>0.05$) for all diets. No significant changes were found in consumption patterns of any of the rations fed between the first and last week of the experiment.

Key Words:PALATABILITY, STARTER PIGS, CANOLA MEAL, SOYBEAN MEAL.

B. Introduction

Studies involving the replacement value of canola meal (CM) for soybean (SBM) in starter pig diets have shown, with few exceptions, that as the level of CM in the diet was increased there was a concomitant decrease in performance. McKinnon and Bowland (1977) and Castell (1977) reported

significant reductions in starter pig performances when CM was included in the diet at levels of 25.3 and 7.5%, respectively. More recently, McIntosh and Aherne (1983) have shown that for each one percent addition of CM to the diet, average daily gain (ADG) and average daily feed intake (ADF) were reduced by 2 and 4 g, respectively. This relationship ($P<0.001$) resulted in a significant decrease in pig performance when CM replaced 75% or more of the protein supplied by SBM (27% or more CM in the diet).

Possible reasons for the reduction in feed intake of diets containing CM when fed to starter pigs may be the influence of glucosinolates on thyroid function (McKinnon and Bowland 1979; Ochetim *et al.* 1980) and/or the reduced palatability of the meal associated with presence in the meal of tannins, phytic acid, sinapine, glucosinolates and their breakdown products and fiber (Chubb 1982).

Since the decrease in performance noted when CM was included in the ration appears to be associated with decreased feed intake, it seemed desirable to determine whether or not this observed reduction in ADF was caused by a decreased palatability of the meal. Consequently, palatability studies were conducted to determine: (1) whether young pigs, when given a choice, would select a diet containing SBM in preference to diets containing varying levels of CM; (2) whether feeding a diet containing CM prior to conducting a palatability study would have any influence on subsequent selection preferences of starter pigs given a

choice between a SBM and a CM supplemented diet and (3) whether the consumption level of starter pig diets containing CM replacing 50 or 100% of the SBM in the diet would be affected by the inclusion of three feed flavour additives.

C. Materials and Methods

Experiment One

Sixteen crossbred (Yorkshire x Lacombe) pigs (five weeks of age) equalized for sex and with an average initial weight of 9.6 ±0.5 kg were assigned to a 28 day study. Animals were randomly allotted to one of four groups on the basis on initial weight in a replicated 4x4 Latin square design. Each of the four test periods lasted seven days. Each group was given the choice of a SBM supplemented diet (#0) and one of four experimental diets containing either 5, 10, 15 or 20% CM (#'s 1, 2, 3, or 4, respectively, Table IX.1). Thus in any one test period each pig had access to two feeders, one containing the control diet (#0) and the other containing a CM supplemented diet (#'s 1, 2, 3 or 4). The locations of the two feeders in each pen were changed daily.

The five diets were based on barley, wheat and oat groats and were formulated to meet or exceed National Academy of Sciences-National Research Council (NAS-NRC 1979) recommended levels of nutrient requirements. The diets were formulated to be isonitrogenous on an as fed basis, to be

isoenergetic on a digestible energy basis and were equalized for total lysine content by the addition of synthetic lysine (L-lysine hydrochloride, 78%). Commercially available CM (cv Candle) was added to the diets at the expense of SBM and barley.

Pigs were kept in individual flat deck pens (0.6 X 1.2m) with feed (mash form) and water available *ad libitum*. The environmental temperature was maintained at 23°C throughout the 28 day study.

The percent crude protein, gross energy, dry matter and ether extract of the feed samples were determined according to the Association of Analytical Chemists (AOAC, 1975). Total dietary lysine levels were determined, following acid hydrolysis in 6 N HCL (Blackburn 1968), on a Beckman 121MB amino acid analyzer.

Feed consumption data (expressed as a percentage of the total intake of the two diets offered) and weight gains were measured daily and data combined for day 1, days 1-3 and days 1-7 of each period. Data obtained for each dietary combination and their analogous ARC-SINE transformations were analyzed for significance according to Least Squares analysis of variance procedures as described by Harvey (1975). Where appropriate, treatment means were tested for significance ($P<0.01$) using Student-Newman-Keul's (SNK) multiple range test when preceded by a significant F test (Steele and Torrie, 1980).

Experiment Two

Twelve crossbred pigs with an initial weight of 8.2 ±.8 kg were divided at random into six groups of two pigs (one barrow and one gilt) each, placed in individual pens and were managed in the same way as in Experiment One. Feed consumption and weight gains were measured at 4 day intervals.

Initially all twelve pigs were fed a 20% protein starter diet (Table IX.1, Diet #2) containing 10% CM. After 4 days one group of pigs (one barrow and one gilt) were given a choice between the CM diet and a SBM control diet (Table IX.1, Diet #0) for the remainder of the trial. Subsequently, after each 4 day interval another pair of pigs were given a choice between the CM and SBM supplemented diets (Fig. IX.2). Thus pairs of pigs were adapted to the CM supplemented diet for 4, 8, 12, 16, 20 and 24 days before being offered a choice between the 10% CM diet and the SBM control diet.

Due of the nature of the experimental design, it was necessary for ease of interpretation, to statistically analyze the data for significance ($P<0.05$) in four groupings. These groupings were based on the combination of: (1) days given a choice between CM and SBM; and (2) days of adaptation to CM as follows:

Groups	Days Given a Choice	Days of Adaptation
I	4, 8, 12, 16, 20	4, 8
II	4, 8, 12, 16	4, 8, 12
III	4, 8, 12	4, 8, 12, 16
IV	4, 8	4, 8, 12, 16, 20

The variables analyzed were: (1) quantity of CM consumed (kg); (2) CM consumed as a percent of total consumption; and (3) CM vs SBM consumed (kg). Variables (1) and (2) were analyzed using a 2-way Analyisis of Variance (ANOVA) with days given a choice and days of adaptation to CM as factors. Variable (3) was analyzed using a 3-way ANOVA with days given a choice, days adaptation to CM and the two diets as factors. Data analysis of variance was performed according to Steele and Torrie (1980). Where appropriate, treatment means were tested for significance ($p<0.05$) using Student Newman Keul's multiple range test when preceded by a significant F-test.

Experiment Three

Two hundred and sixteen crossbred (Yorkshire x Lacombe) pigs (four weeks of age) equalized for sex and with an average initial weight of 7.4 ±0.2 kg were randomly allotted to one of nine dietary treatments on the basis of initial weight. The diets were based on wheat, barley and oat groats and were formulated to meet or exceed National Academy of Sciences-National Research Council (NAS-NRC 1979) recommended levels of nutrient requirements (Table IX.3). The diets were formulated to be isoenergetic on a digestible

energy basis and isonitrogenous on an as-fed basis. The CM (cv Candle) was added to eight of the diets replacing either 50 or 100% of the protein supplied by the SBM supplement (17 and 34% CM in the diet, respectively).

The diets containing CM were supplemented with or without 0.15% monosodium glutamate (MSG), 10% dextrose or 4-5% corn oil. The diets containing CM were supplemented with lysine-HCL to a level equal to the calculated available lysine level of the SBM control diet using the fecal data of Sauer *et al* (1981) and Sauer *et al* (1982). The percent crude protein, gross energy, dry matter, ether extract and the lysine levels in the diets were determined as in Experiment One.

Forty-five pairs of pigs (one barrow and one gilt) were housed in 1.2 X 1.2 m slatted floor pens and 63 pairs of pigs were housed in 0.6 X 1.2 m flat decks with Tenderfoot flooring. The pairs of pigs were allowed *ad libitum* access to feed (mash form) and water. Pigs were weighed weekly and feed consumption was determined on a pen basis at the time of weighing. The environmental temperature was maintained at 23°C throughout the 28 day study.

Analyisis of variance of the data was performed according to Steele and Torrie (1980). Where appropriate, treatment means were tested for significance ($P<0.05$) using Student Newman Keul's (SNK) multiple range test when preceded by a significant F test.

D. Results and Discussion

Experiment One

When given a choice, starter pigs preferred ($P<0.01$) the SBM control diet (#0) more than any of the four CM supplemented diets (#'s 1, 2, 3 or 4, Table IX.2) over the three time periods studied. There was also a significant decrease ($P<0.05$) in consumption of the CM diets as the level of CM in the diet increased from 5 to 20% on days 1-3 and 1-7 (Fig. IX.1). These differences were consistent with the ARC-SINE transformation analysis. Average daily gain (ADG) and feed conversion effeciency (FCE) were not affected ($P>0.05$) by the dietary combination offered.

Starter pigs were able to detect ($P<0.05$) the presence of CM at a level as low as 5% in the diet, consuming two and one half times more of a SBM control diet. As the level of CM in the diet reached 20%, pigs consumed seven times more of the SBM control diet than the CM diet when given a choice. The results from this study indicated that when given a choice, starter pig preference for diets supplemented with CM decreased ($P<0.05$) as the level of CM in the diet increased. The reason for the decreased preference for diets containing CM was not apparent.

Possible reasons for the reduction in feed intake of CM supplemented diets by starter pigs may be due to some of the anti-nutritive factors present in the meal (Singham and Lawrence 1979; Chubb 1982). Factors such as sinapine (Mueller *et al.*1978; Goh *et al.* 1982), tannins (Leung *et*

al.; Mitura 1982), glucosinolates and their breakdown products (nitriles, isothiocyanates, thiocyanates) (McKinnon and Bowland 1977; Ochetim *et al.* 1980)and fiber (Aherne and Kennelly 1982; Bell and Shires 1982) alone or in combination, may have had a negative effect on the feed intake of the starter pigs.

Experiment Two

The results obtained (Fig.IX.2) indicated that prior adaptation for 20 days of starter pigs to a 10% CM supplemented diet did not significantly increase their subsequent acceptance of the meal. When the pigs were allowed a choice between the CM and SBM diets, they consumed significantly ($P<0.01$) more of the SBM supplemented diet than the diet containing 10% CM regardless of their prior adaptation to the 10% CM diet.

The overall consumption of the CM and SBM diets by starter pigs, ranging from 8.2 to 24.2 kg liveweight, was 24.0 and 76.0% of their total feed intake, respectively. These values compare favourably with 24.4 and 75.6% obtained in Experiment One for the consumption of the 10% CM diet and the SBM control diet, respectively, by starter pigs without prior adaptation to CM (Fig.IX.1).

Experiment Three

No signifcant differences in pig performance from 7.4 to 18.0 kg liveweight were attributed to the inclusion of 0.15% MSG, 10% dextrose or 4-5% corn oil in CM supplemented diets (Table IX.4). Pigs fed a SBM control diet and a 50/50

SBM/CM supplemented diet containing dextrose grew faster ($P<0.05$) than pigs fed the 100% CM supplemented diet with or without the flavour additives. Pigs fed the 50/50 SBM:CM diet containing dextrose consumed more ($P<0.05$) feed than pigs fed the 100% CM supplemented diet with or without the flavour additives. Feed conversion efficiencies were similar ($P>0.05$) for all diets. No significant changes were observed in the feed consumption patterns of pigs fed any of the rations in the first and last week of the experiment.

Although no response was observed in this study, the taste modifier MSG has been shown to suppress acuity of undesirable flavors and increase food consumption (Aldinger 1969; Goatcher and Church 1970). Fenaroli (1970) however, suggested that MSG can enhance the pungent flavor of thioisocyanates to intolerable levels, thus reducing dietary acceptance. The addition of dextrose or different types of fat to swine diets have been shown to stimulate feed intake (Speer 1976; Chapple *et al.*1982). In the present experiment there were no significant differences in consumption between CM supplemented diets with or without 0.15% MSG, 10% dextrose or 4-5% corn oil.

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Table IX.1. Formulation and chemical composition of the soybean meal (SBM) supplemented diets containing either 0, 5, 10, 15 or 20% canola meal (CM) (#'s 0, 1, 2, 3 or 4, respectively).

Diets No's:	#0	#1	#2	#3	#4
Diets:	SBM control	5%CM	10%CM	15%CM	20%CM
Criteria					
Ingredients (%):					
Wheat	25.0	25.0	25.0	25.0	25.0
Barley	21.5	20.48	18.47	16.46	15.43
Oat groats	20.0	20.0	20.0	20.0	20.0
Soybean meal (43.6% CP[1])	26.5	22.5	19.0	15.5	11.5
Canola meal[2] (36.8% CP)	---	5.0	10.0	15.0	20.0
Blended animal fat	3.0	3.0	3.5	4.0	4.0
Iodized salt	0.5	0.5	0.5	0.5	0.5
Calcium phosphate	1.5	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0	1.0
L-lysine HCL (78%)	---	0.02	0.03	0.04	0.07
Starter premix[3]	1.0	1.0	1.0	1.0	1.0
Chemical Analysis[4]:					
Dry matter (%)	89.1	89.4	89.3	89.3	89.1
Crude protein (%)	20.6	20.8	21.5	21.1	21.0
Lysine (%)	1.16	1.21	1.26	1.28	1.26
Ether extract (%)	5.3	5.9	6.2	7.2	7.2
Digestible energy (MJ/kg)[5]	14.18	14.10	14.14	14.18	14.10

[1] CP, crude protein.

[2] Canola meal contained the following levels of glucosinolates (mg/g): 3-butenyl, 0.37; 4-pentenyl, 0.15; and 2-hydroxy-3-butenyl, 0.59 as analyzed by the POS Pilot Corp, Saskatoon, Sask.

[3] Starter premix provided the following per kg of diet: 120.0 mg zinc, 12.0 mg manganese, 150.0 mg iron, 12.0 mg copper, 0.1 mg selenium, 5000 IU vitamin A, 700 IU vitamin D-3, 23 IU vitamin E, 12.0 mg riboflavin, 45 mg niacin, 25 mg calcium pantothenate, 30 ug vitamin B-12, 500 mg choline chloride, 275 mg ASP250

[4] Determined values reported on an as-fed basis unless otherwide reported.

[5] Calculated according to NAS-NRC (1979) recommendations of DE values of feed ingredients commonly used in swine rations.

Table IX.2. Average performance of pigs when given a choice between a soybean meal (SBM) control diet (#0) and one of four diets containing 5, 10, 15 or 20% canola meal (CM) (#'s 1, 2, 3 or 4, respectively).[1,2]

Dietary choices:	#0 vs #1 (SBM vs 5%CM)	#0 vs #2 (SBM vs 10%CM)	#0 vs #3 (SBM vs 15%CM)	#0 vs #4 (SBM vs 20%CM)	SE[3]
Criteria					
Performance[4]:					
Initial wt. (kg)	9.1	10.2	9.0	9.9	0.67
Final wt. (kg)	26.6	26.9	25.4	26.8	0.49
Daily gain (g)	627	597	586	606	45.8
Daily feed (g)	1139	1122	1089	1117	97.2
Feed:gain	1.82	1.88	1.86	1.83	0.03
Diet Preference[5]:					
Day 1	(75.9% vs 24.1%)	(78.9% vs 21.1%)	(83.1% vs 16.9%)	(84.9% vs 15.1%)	3.8
Days 1-3	(69.8% vs 30.2%)a	(75.4% vs 24.6%)ab	(79.8% vs 20.2%)bc	(85.3% vs 14.7%)c	3.1
Days 1-7	(71.6% vs 28.4%)a	(75.6% vs 24.4%)a	(84.9% vs 15.1%)b	(87.5% vs 12.5%)b	2.4

[1] All feed consumption comparisons between SBM and CM (all levels) are significantly different ($P<0.01$).

[2] a,b,c, means within the same row with the same or no letter are not significantly different ($p<0.05$).

[3] SE, standard error of the mean.

[4] 16 pigs per dietary comparision (16 replications of one pig).

[5] All diet preference comparisons (percentage of total intake) showed the same significant ($P<0.05$) treatment differences when the percentages were changed to Arc-Sine transformations and subsequently analyzed.

Table IX.3. Formulation and chemical composition of soybean meal (SBM) and canola meal (CM) supplemented diets containing various feed flavour additives.

Diets:	SBM Control	50%SBM 50%CM	100% CM	50%SBM 50%CM + MSG	100%CM + MSG	50%SBM 50%CM+ Dextrose	100%CM + Dextrose	50%SBM 50%CM+ Corn Oil	100%CM + Corn Oil
Criteria									
Ingredients (%):									
Wheat	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Barley	21.5	16.88	11.77	16.88	11.77	5.92	1.78	16.88	11.77
Oat groats	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Soybean meal (44% CP)[1]	26.5	13.5	----	13.5	----	15.0	----	13.5	---
Canola meal (37% CP)	----	16.5	34.0	16.5	34.0	18.0	36.0	16.5	34.0
MSG[2]	----	----	----	0.15	0.15	----	----	----	---
Dextrose[3]	----	----	----	----	----	10.0	10.0	----	---
Corn oil[4]	----	----	----	----	----	----	----	4.0	5.0
Blended animal fat	3.0	4.0	5.0	4.0	5.0	2.0	3.0	----	---
Iodized salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calcium phosphate	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
L-lysine HCL (78%)[5]	----	0.12	0.23	0.12	0.23	0.08	0.22	0.12	0.23
Starter premix[6]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chemical Analysis[7]:									
Dry matter (%)	91.1	91.8	90.3	89.9	91.5	88.9	89.3	90.2	90.9
Crude Protein (%)	20.4	20.8	22.6	20.5	21.9	20.6	21.3	19.8	22.3
Lysine (%)	0.86	0.97	1.18	0.96	1.08	0.93	1.05	0.94	1.12
Ether extract	5.1	7.2	8.8	7.6	8.4	5.3	6.3	7.9	9.0
Digestible energy (MJ/Kg)[8]	14.17	14.15	14.12	14.15	14.12	14.07	14.02	14.15	14.12

[1]CP, crude protein.

[2]MSG, monosodium glutamate (L-Glutamic Acid), no. G-1626., Sigma Chemical Co., St. Louis, Mo.

[3]Dextrose 2001 regular (Cerelose), Corn Products, Englewood Cliffs, N.J.

[4]Commercially available Mazola corn oil to which ethoxyquin (Delquin, 50%) was added at a level of 125 ppm.

[5]Calculated according to Sauer *et al* (1981) and Sauer *et al* (1982) for fecal lysine availabilities: wheat, 79%; barley, 74%; SBM, 88%; CM, 78%.

[6]Starter premix provided the following per kg of diet: 120 mg zinc, 12.0 mg manganese, 150 mg iron, 12 mg copper, 0.1 mg selenium, 500 mg choline chloride, 5000 IU Vitamin A, 700 IU Vitamin D-3, 23 IU Vitamin E, 12 mg riboflavin, 45 mg niacin, 25 mg calcium pantothenate, 30 *ug* Vitamin B-12, 275 mg ASP250.

[7]Determined values reported on an as-fed basis unless otherwise indicated.

[8]Calculated according to NAS-NRC (1979) recommendations of DE values for feed ingredients commonly used in swine rations.

Table IX.4. The average performance of starter pigs fed soybean meal (SBM) and canola meal (CM) supplemented diets containing various feed flavour additives.[2]

Diets:	SBM control	50%SBM 50%CM	100% CM	50%SBM 50%CM+ MSG[3]	100%CM + MSG	50%SBM 50%CM+ Dextrose	100%CM + Dextrose	50%SBM 50%CM+ Corn Oil	100%CM + Corn Oil	SE[1]
Criteria										
Performance[4]:										
Initial wt.(kg)	7.4	7.3	7.5	7.3	7.3	7.4	7.4	7.3	7.3	0.23
Final wt. (kg)	18.1a	17.5abc	16.4abc	17.1abc	15.8c	18.0ab	16.3bc	17.3abc	16.1c	0.58
Daily gain (g)	383a	365ab	320bc	349abc	304c	380a	315bc	355ab	312bc	13.8
Daily feed (g)	637ab	615abc	535c	605abc	530c	660a	562bc	606abc	564bc	21.7
Feed:gain	1.66	1.68	1.67	1.73	1.73	1.72	1.78	1.70	1.80	0.04

[1]SE, standard error of the mean.

[2]a-c, means within rows with the same or no letter are not significantly different ($P<0.05$).

[3]See Table 3.

[4]24 pigs per dietary treatment (12 replications of two pigs).

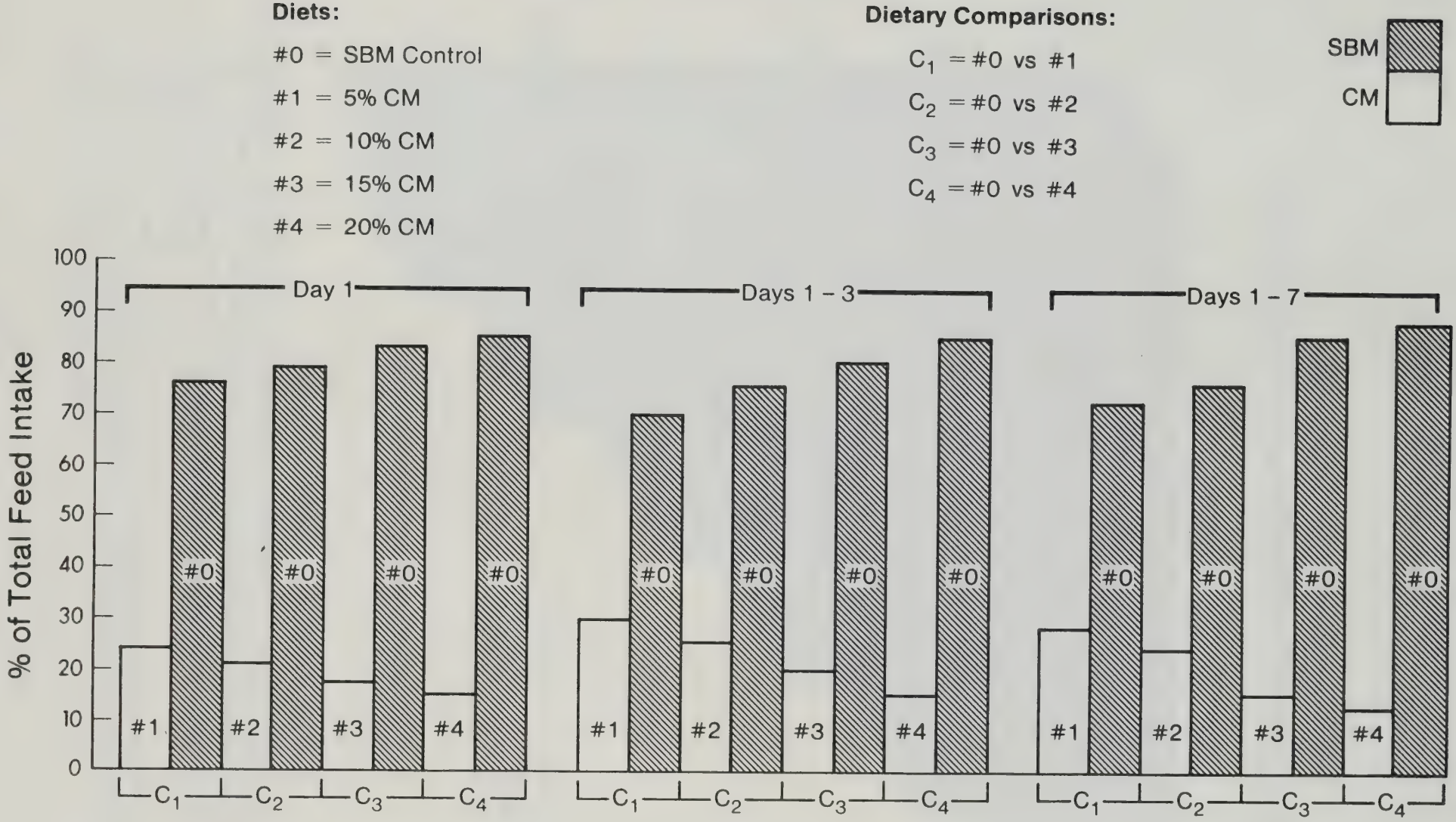

FIG. IX.1 *Diet selection comparisons (% of total F.I.) of different levels of CM (#1, 2, 3 or 4) to a SBM control (#0) on three different days of each period.*

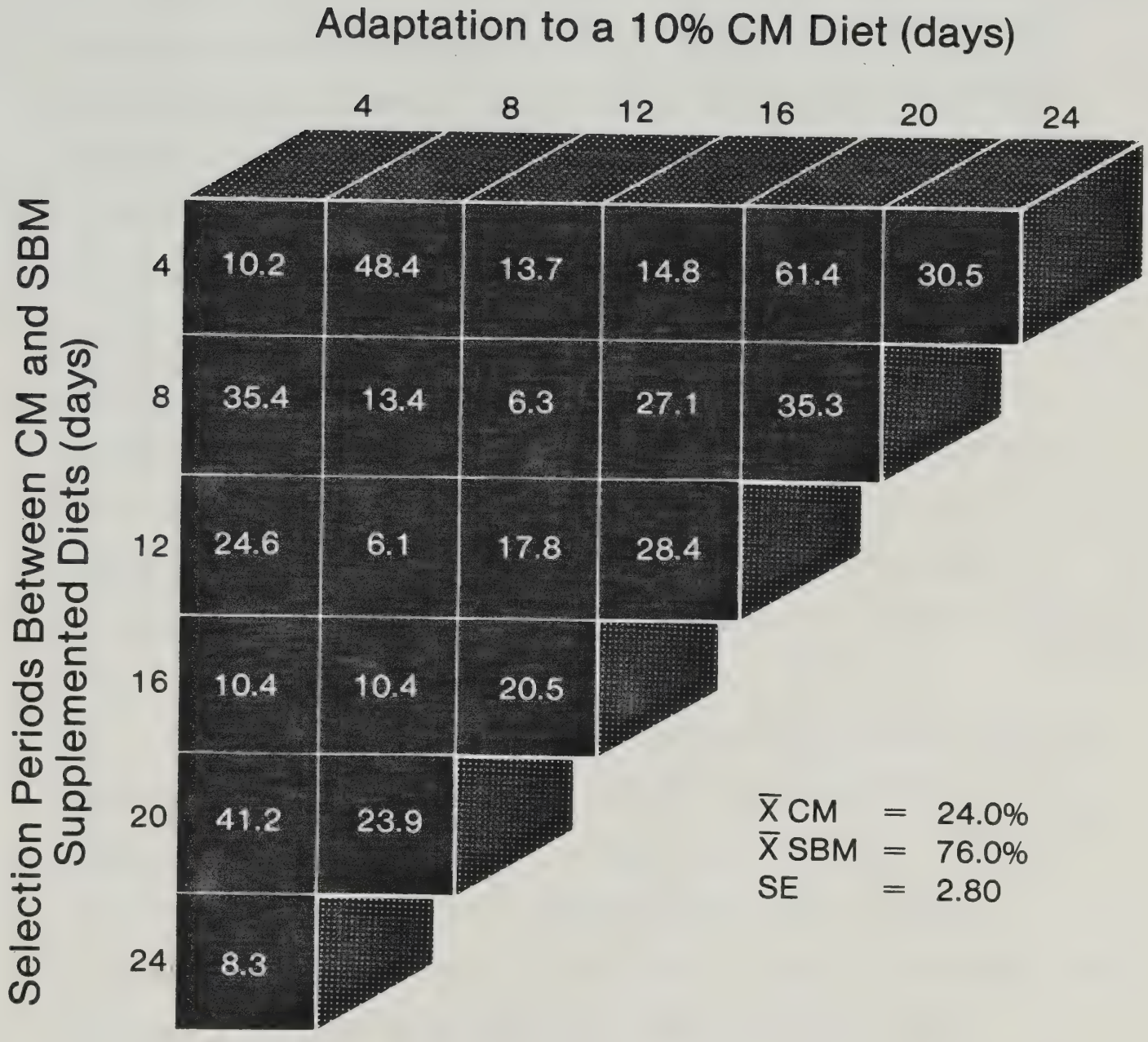

FIG.IX.2 Percent consumption of a diet containing 10% Canola Meal (CM) by starter pigs when given a choice between the CM diet and a Soybean Meal (SBM) control diet following 4-24 days adaptation to the CM diet.

(Each number within a block represents the amount of CM consumed during a four day selection period expressed as a percentage of the total intake of two diets offered during that period.)

X. CONCLUSION

The results of the first two feeding trials suggest that CM (cv Candle) may replace up to 50% of the protein supplied by the SBM supplement (17-18% CM in the diet of starter pigs) without significantly affecting performance. Each one percent addition of CM to the diet resulted in a linear ($P<0.05$) reduction in average daily feed intake (ADF) and average daily gain (ADG) of 4 and 2 g, respectively. It is of interest to note that the conversion of feed to body weight gain and the digestibility coefficients for dry matter and nitrogen were not affected by the level of CM in the diet. The supplementation of lysine-HCL did not significantly improve the performance of starter pigs fed grain-based diets containing CM relative to the SBM control diet.

The apparent digestibility coefficients for dry matter and energy decreased linearly as the level of protein from CM increased in the diet. The apparent N digestibility and apparent net protein utilization (NPU) also linearly increased as the protein content of the diet increased. The apparent and true N balance increased ($P<0.05$) with increasing protein levels. The apparent fecal availabilities of most of the indispensable and dispensable amino acids increased linearly ($P<0.05$) and/or quadratically ($P<0.05$) as the level of protein in the diet increased. The true biological value and NPU of CM for starter pigs was 70.1 and 57.3, respectively. It appears from this study that the

increasing levels of fiber had a greater reducing effect on the utilization of dry matter and energy than on nitrogen.

The results of the palatability studies would indicate that when given a choice, regardless of prior exposure to diets containing CM, pigs exhibit a significant preference for SBM supplemented diets than diets containing CM. As the level of CM in diets increased from 5 to 20%, pigs, when given a choice, consumed significantly more of a SBM supplemented diet than a diet containing CM. The inclusion of 0.15% monosodium glutamate (L-Glutamic acid), 10% dextrose and 4-5% corn oil had no significant influence on the consumption of diets in which CM replaced either 50 or 100% of the SBM supplement (on a nitrogenous basis).

Whether the observed reduction in feed intake by starter pigs of diets containing CM is due to the palatability of the meal (glucosinolates, tannins, sinapine, fibre, bitterness or pungency), amino acid availability (other than lysine) or due to the effect of the glucosinolates on thyroid function and overall metabolism is unknown at this time.